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ROAD BUILDING.

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AN INFORMAL DISCUSSION PRESENTED AT THE MEETINGS OF THE SOCIETY ON SEPTEMBER 21ST AND NOVEMBER 2D, 1898.

JAMES OWEN, M. Am. Soc. C. E.—The question of road construction in latter years has assumed a somewhat different aspect from that which it bore some five or six years ago when the subject was rather thoroughly discussed by the members of this Society. Mr. Owen.

Attention should be called to what may be termed the competition in the road question as evidenced by the lowering of the prices for ordinary street pavements. The speaker remembers the time when the cost of building a telford pavement was about $2 per yard. To-day asphalt pavements are being built at a cost of about $1.38 per yard, and the engineer, in selecting a pavement,—if he has any discretion in selecting—might suggest to his clients that it might be better in many places to choose a permanent street pavement, at the lower price which it now costs, than an ordinary macadam road. This idea is advanced because it seems to solve a good many prob-

Mr. Owen. lems. The construction of macadam or telford roads extends through different territories and different kinds of population, and can be divided into what may be called mural, suburban and rural. Now, each of these kinds of road requires, to a certain extent, a special treatment, as far as construction for the travel and the available funds with which to construct it are concerned; and it seems to the speaker that it would probably be better to confine the discussion to rural roads, because in the future more permanent and less destructible pavements will be substituted in a great many cases, where macadam would now be built.

There are two points to which attention should now be called: *First*, the material; and, *second*, the handling and laying of the material. Some years ago the speaker read a paper* before this Society, and stated that he did not believe in thin pavements, or in anything but a telford pavement, as far as macadam was concerned, in ordinary circumstances. His mind has not very materially changed in this respect, and he still adheres to the principle, both in theory and practice. Mr. Leutzé states that he put down an 8-in. macadam road. The speaker hardly thinks this is a wise practice, and believes that a road would be cheaper, very serviceable, and would give better results if 5 ins. of telford and 3 ins. of macadam were used instead of 8 ins. of macadam only. In the first place, in most parts of the country there is available local stone, which is not perishable, which can be used for a foundation, leaving only the final finish of 3 ins. to be provided from other sources. In the speaker's opinion, it is cheaper, in the majority of cases, to build an 8-in. or a 10-in. telford than an 8-in. macadam, and the final results are much better.

The next problem is the question of the selection of stone. It is conceded, on all hands, that trap rock is the *sine qua non* for macadam and telford pavements. There are different kinds of trap rock and they work differently in treatment, but it probably will be agreed by all that a trap rock pavement, if it can be built as cheaply, or even at a slightly greater cost than other stone, is the best. Certain country roads built with granite of rather a soft quality, have been examined by the speaker, and, for the use to which they are put, they are quite successful. A well-selected granite, in one or two respects, is preferable to trap; it is more friable, and, though it wears out a little faster, it does not break up in dry weather, and where it can be had with a short haul there is no specific objection to it. Of course, granite containing too much mica will not be successful.

In a limestone country, if properly handled, properly laid and judiciously finished, successful results can be had with a good limestone road. Its defects are known. It grinds out more easily than either trap or granite. It is dusty. It is also known that a limestone road

* *Transactions*, Am. Soc. C. E., Vol. xxvi, p. 603.

is much preferable to any other construction, except either trap or granite. Mr. Owen.

Then there is the local use of the shales and gravels without treatment. Construction of a permanent gravel road on an aboriginal granite foundation can hardly be classified as an engineering improvement in the way of roads. Yet the proper use of gravel, carefully handled, thoroughly rolled and well selected, can make a very satisfactory road for Mr. North's suggestion of nine months in the year, but not for more than the nine months. There are also the shales, which can be treated and make really a better road for nine months in the year than limestone.

In naming these materials, nearly all the material for roads in this section of the country has been exhausted. In the southern States there are other materials. In Tennessee there is an excellent natural material that makes fair traveling roads; and, of course, in the South, roads are not so apt to be broken up by frost, and all the care necessary is to keep the water away and keep them from washing out.

In regard to the size of the stone, the speaker some years ago laid down as a principle that all stone for roads should pass through a $1\frac{3}{4}$ or $1\frac{1}{2}$-in. ring. He has modified this view, having found that the locality of the roads should be considered, and now he classifies the sizes of the stone according to the character of the travel. While a very satisfactory driving road can be secured from $1\frac{1}{2}$-in. stone, for ordinary country travel and for nice driving travel in a suburban community, the same cannot be said where travel is heavily congested; and, of late years in his practice, the size has been increased to from 2 to 3 ins., not only on the score of economy, but to secure better results and a better and more uniform surface; while, by the abandonment of the ideal $1\frac{1}{2}$-in. stone, the smooth surface is sacrificed, and a generally better average result is obtained by the use of the larger stone. It does not do to have the sizes mixed. If a road is built with $2\frac{1}{2}$-in. or 3-in. stone, it should be all $2\frac{1}{2}$-in. or 3-in.—no dust, no small stone intermixed. If on a road there is a patch of 2-in. stone, and then beyond that a little patch of $1\frac{1}{2}$-in., the latter will wear out more quickly than the former, and in a year or two there will be an uneven surface, which should be avoided. The speaker wishes here to emphasize this point to those who manage the industry, in which a large amount of capital is invested, of breaking stone for the market. The difficulty is that in the arrangement of the crackers and the adjustment of the screens sufficient consideration is not given to separating the uniform sizes of stone to be delivered. The men who handle the stone crackers and stone breakers are too apt to dump it in a heap, and if 2-in. stone is asked for, the answer is: "We will give you a little finer, but it doesn't hurt." It does hurt. The use of anything but uniform sizes is a material drawback to the

Mr. Owen. final success of the road. If engineers will insist on that point, the result on the wear and tear of the roads will be much more satisfactory, not only to the engineer, but to the community.

The question of the top finishing of the road is a matter about which the speaker is not particularly solicitous. The top finishing of a road is an accessory. If on a heavily traveled road a coating of dust is placed, it probably will last from one to three months, after which the travel is down on the hard wearing surface below. In roads that are constructed for fancy driving, dust is a very pleasant accessory, and is desirable on that account; on a rarely traveled country road it is very desirable because it prevents the breaking up of the stone surface below in dry weather, and, to a certain extent, prevents wash in very wet weather. Generally speaking, however, the question of the dust is not of importance. A suggestion, however, has been made that a mixture of the trap rock as the ideal stone and the limestone, which has a better cementing power, might be advisable.

Another point of which mention might be made is a much controverted question—the packing, that is, the injection of extraneous matter with the stone for the purpose of binding. This packing is nothing but a temporary expedient to get the road down to its permanent condition, and, as such, is a detail of construction and not a permanent factor in the wear and tear of the road. A great deal of controversy has arisen as to whether gravel, sand, clay or loam is the best material for packing. In the speaker's experience almost any available material, carefully selected, will do the work required of it. Gravel or sand may be used, but the speaker does not recommend either. Clay should be used very sparingly. Ordinary earth, or loam, as it is called here, is about the most efficacious material to use for the purpose of getting a road down speedily. Clay is treacherous. The speaker has known a piece of road to be utterly ruined by an overdose of clay in its construction. It breaks the road up continuously, and the damage is never rectified until another coating is put on to eliminate the original error. It is merely a question of judgment on the part of the engineer as to how he will use packing, and in using that judgment the element of weather is the most important consideration, outside of the question of the character of the stone itself. A hard Orange Mountain stone needs a great deal more packing to get it down than does the Bergen trap stone, and a Bergen trap stone needs a great deal more than granite. The granite wants very little. The limestone wants hardly any at all. The shale furnishes its own packing. But, going back to the point mentioned, the weather is an important consideration in this item of of packing—not only the weather as it is to-day, but the probable weather conditions that may exist in the two or three months before the road is finally consolidated. If a period of dry weather can be

anticipated, it is reasonable and desirable that a great deal more packing should be used than if the road is built late in the fall when there is a prospect of wet weather ahead. In the latter case packing should be used very sparingly. It is entirely a matter of experience and judgment. If care is used in the selection and application of the packing, a great deal of the trouble that engineers find in building roads throughout the country, and the criticisms made that the packing should not be there, does not belong there, and that it is a fraud on the part of the contractor to put it there, will be eliminated. Mr. Owen.

The speaker has known whole communities torn to pieces on the question of packing, and governing bodies indicted on the question, simply because the public mind was not educated as to what was proper practice at that place and time.

There is one other point which bothers all who are building roads, namely, the interjection of a trolley track in the middle of a telford pavement, and it is very important that it should be discussed. The conditions of maintenance of a pavement with a trolley track in it are entirely different from the conditions of the ordinary road on which the travel is uniformly spread over the entire surface. The laying down of a rail, and the laying of a pavement on each side of the rail, causes a distinct and well-defined line of travel on each side of the track. The trouble is that instead of the pavement wearing uniformly over its surface, that *bête noire* of all road engineers—the rut—is started. This question of ruts is one of the most important with which we have to deal. In the last two or three years the speaker's practice has been changed altogether. Instead of 2½-in. stone he uses 3-in. stone, and each side of the track is made a separate roadway of itself with its own individual crown. The experiment of putting a coating of gravel on the top pavement, at first as a matter of economy, has also been tried. Experience shows that the increase of wear and tear and the cost of maintaining a similar area of roadway on each side of a trolley track is about twice what it would be with the ordinary condition of a single macadam or telford road. In Providence, which is practically a macadam city, the same problem has arisen. It is honeycombed with trolley tracks like all American cities, and in maintaining the roads larger stone is being used. The City Engineer of Providence in 1897 said, in reply to a question, that the final result arrived at there was to rip them all out. It may be that that will be the only solution. Up to now there has been no satisfactory solution of the maintenance of that kind of road-bed.

W. E. McCLINTOCK, M. Am. Soc. C. E.—In Massachusetts, in 1892, a temporary Commission was appointed to investigate the whole topic of road building in that State. In 1893 the Commission was made permanent. In 1894 it was given an appropriation of $300 000; in 1895 it was given $500 000; in 1896, $600 000; in 1897, $800 000, and in Mr. McClintock

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1898, $400 000, all of which was to be expended upon roads petitioned for by the Selectmen of the different towns or the Commissioners of the different counties.

A comprehensive scheme was first laid out, which included main roads throughout the length and breadth of the Commonwealth, amounting in the aggregate to about 2 000 miles, and an effort was made to direct the petitioners, to a certain extent, so that the roads petitioned for might form parts of a completed whole. Up to the present time there have been received by the State Commission 460 different petitions, covering 1 094 miles of road, and of these petitioned roads there have been laid out and constructed 223 miles. Each mile of road which has been constructed forms a part of one of the main roads before mentioned. The Commission at the beginning of its work selected the most difficult roads for treatment, the object of this action being two-fold: first, to better the entire road by removing the heaviest obstructions to travel, and, second, to show a reduced average cost rather than a uniform or increasing cost. In taking the cost of work, as it has been carried out in Massachusetts, this fact must always be borne in mind. The average cost of the work done by the Commission has been $10 300 a standard mile, of broken stone road 15 ft. wide, with gravel shoulders 3 ft. wide on each side of the stone, and including the incidental items of grading, draining, foundation, culverts, bridges, fencing, engineering, etc.

When road engineers fail to agree, the probabilities are that their conditions are entirely different. In describing the work which has been done by the Commission in Massachusetts, perhaps it might be well to first outline the conditions which are to be found there.

The topography of the State may be generally described as follows: Cape Cod, a narrow strip of land, extends from 60 to 80 miles into the sea, and is the eastern part of the State. In the main it is made up of sand, with a high moraine ridge, extending lengthwise through the center. This moraine is made up mostly of a hard, boulder till, with large masses of schist, slate, and granite, either embedded in the till or scattered over the surface. The south side of the moraine is of a sandy nature and devoid of stone. The north side of the moraine is well supplied with field stone, mostly granitic, in sizes varying from a few inches to many feet in diameter. There are a few available banks of clay. Back of the Cape Cod district is the main easterly shore belt, about 10 to 12 miles wide, which is of volcanic origin, abounding in trap, felsite, granite and conglomerate, any one of which stones makes good road material, while some of them are of the best quality for this purpose. Then, working westerly, there is a broad area known as the Worcester Plateau, mostly drift. The native rock in this section is either schist, slate or gneiss, none of which can be advantageously used in the construction of roads. Westerly of the Worcester Plateau

comes the Connecticut Valley, with a long ridge of high hills, made up almost entirely of trap rock, beginning near the northern end of the State, following the river across the State and continuing into and across Connecticut. Westward of the Connecticut Valley is another level area in which is to be found a poor grade of field stone, but no good ledges. Then comes the Berkshire Hills district, which is practically devoid of good road material, the main Berkshire Hills being composed of schistose and lime rocks, with small quantities of quartzite. Mr. McClintock

Large crushing plants have been set up at various points on the lines of railroads, and these supply broken trap rock to different parts of the Commonwealth. The stone thus delivered varies in price from $1 to $1.40 per ton on the car at its destination. All the larger communities can be supplied economically in this manner, but when the road to be built lies two or more miles from the delivery point, the increased cost of haulage over the highway makes it necessary to abandon the trap and use the native rock, even though it be of poor quality. Quartzite has not given good results, as it lacks binding properties. Schist or slate has not been used. Lime rock has been used in one road, where it gives a good bond, but wears rapidly. Mixed field stone has a good bond, but wears so as to leave the harder stone projecting above the surface. Better results can be obtained if the hard stones be picked out and broken by themselves for use in the wearing course. Some of the harder granitic rocks are difficult to roll, but when thoroughly rolled make a good road. Gneiss and the softer granitic rocks have not been used.

In almost all these territories the country is undulating, with hills varying from 100 ft. to 2 500 ft. high at points traversed by roads, so that the grade problem is an important one, and the cost of grading must be taken into account. The Berkshire Hills district, or the western part of the State, abounds in clay. Over this clay the old roads have been built, and during certain seasons they are practically impassable. The roads of this section, as well as like roads in other parts of the Commonwealth, have been treated specially as clay roads, and the greatest possible care has been exercised to secure good foundations and perfect drainage. In laying out the work, and at the very beginning, the subject of cost was to a certain extent ignored, the object being to get the best road possible, and one which would require the least annual outlay for maintenance. The engineer was instructed to prepare and bring in a plan for as long a road as could be built for a certain stipulated amount of money, say $5 000, $10 000 or $20 000.

His instructions were that a grade of 5% should not be exceeded unless by special vote of the Board. The laws granting damages are so liberally interpreted by all juries in the State, that it has been found necessary to protect every embankment, having a height of say

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2 ft. or more, by a substantial guard rail, and, therefore, this item must be considered in studying the cost of the construction.

The strictest attention has been paid to drainage. Where the road passes over a wet or non-porous soil of any kind, it has been drained in the most substantial manner by placing one drain on the upper side of a scarp road, and on both sides if the road passes through a cut or over a level bottom. These drains have all been given a pitch of not less than 3 ins. per 100 ft. The trenches have been excavated $2\frac{1}{2}$ ft. below the subgrade, the depth increasing on level stretches to give the required pitch. From 2 to 3 ins. of fine, porous gravel was spread over the bottom of each trench after it was excavated. Vitrified clay pipes with bell and spigot joints were placed on this gravel, with the joints open; and around and for 6 ins. over the top was placed gravel free from sand, and which had passed through a $\frac{1}{2}$-in. mesh. Then the remainder of the trench, up to the subgrade, was filled with coarser stones, varying from 1 in. to 3 ins. in their largest diameter. All drains have been carried to an outlet, either to a culvert, to a natural water course, or to a storm sewer.

In passing over clay or a non-porous soil a telford road has been built by using 2 to 3 ins. of gravel, 6 ins. of coarse stone foundation and 4 ins. of broken stone covering. The subgrade was first shaped to the proposed cross-section and grade, carefully rolled and then covered with from 2 to 3 ins. of a porous gravel. On this gravel was placed the telford foundation 6 ins. in depth, laid in the ordinary manner with the large edges of the stones downward, the longest diameter across the road, and each stone self-supporting, not leaning one against the other. The interstices between these large stones were filled carefully with small wedge-shaped stones driven in by maul. The tops were broken off to an even surface. Then the whole surface was evened up with the tailings from the crusher or with other angular stone, and then rolled with a steam roller until it came to a permanent and unyielding foundation. This makes up what is designated as the telford foundation, or the telford road without the top of broken stone, and it has been used, as has been said, on all roads with a non-porous foundation, where it was cheaper to use the coarse stone than it would have been to replace it with broken stone. In many cases better results have been obtained by using broken stone from top to bottom of the road than by using the larger telford stone at the bottom. In placing the broken stone on the road, if it was a telford foundation, it was usually spread to give 5 ins. in the center and 4 ins. on the sides, after a thorough rolling with a heavy steam roller. Without the use of the telford foundation, and over ordinary soil, the broken stone was spread to give a depth of 6 ins. in the center and 5 ins. on the sides after rolling. On a doubtful soil, which could hardly be called a clay or a wet soil, a layer of porous gravel about 2 ins. thick was spread

on the soil before placing the broken stone, the subgrade being first rolled, then covered with the porous gravel, then with the broken stone. Mr. McClintock

All the broken stone was screened into three different sizes by the use of screens with meshes of $2\frac{1}{2}$ ins., $1\frac{1}{4}$ ins. and $\frac{1}{2}$ in. in diameter, so that, when broken stone is referred to in any of these roads, it means stone separated in this manner into $2\frac{1}{2}$-in., $1\frac{1}{4}$-in. and $\frac{1}{2}$-in. stone, or screenings. These have been laid on in courses with the $\frac{1}{2}$-in. size, or the screenings, on top in all cases. On a country road and on all roads where the traffic is fairly light, the coarser or $2\frac{1}{2}$-in. stone has been placed at the bottom, rolled thoroughly, and the surface brought to the exact theoretical distance below the top of the proposed surface with stone of the same size. This has ordinarily been placed to give 4 ins. in depth after being rolled. The $1\frac{1}{4}$-in. stone has been placed on this so as to give 2 ins. depth over the whole surface after rolling, and both of these courses have been rolled thoroughly and evened up with the same sizes of stone used in the respective courses. Ordinarily, no water was applied, up to this period. Then the surface was covered with the screenings, or that part of the broken stone which had passed through the $\frac{1}{2}$-in. mesh. These were thoroughly watered before being rolled ; in fact, they were drenched, so that the water passed out at the sides of the road. Then they were rolled until the finer dust in the screenings flushed to the surface, and the road was opened to traffic and kept open.

There are some roads which may be injured by the application of water even at this point. On a sandy loam road, a loamy road or a clay road over which the telford has been laid, the application of large quantities of water at this time, when the whole mass of stone is porous and open, is likely to cause puddling of the underlying soil or the subgrade, and the settlement of the larger stone of the telford or the smaller stone of the macadam; so that after a while the section of the road will become misshaped and the stone will begin to wave in front of the roller. Then, of course, the rolling process must be discontinued sufficiently long to let the road dry out, and when it is again resumed, an excessive use of water must be avoided.

In the selection of the stone, due consideration is given to its hardness and toughness. Generally speaking, trap rock is the best which can be used, although the traps which are available vary greatly in their value. The lowest grade of trap used in the Massachusetts work has a specific gravity of about 2.7, while the highest grade has a specific gravity of 3.07 or 3.08, making a difference in the weight of a little over 10%, and in the cost of fully $600 a mile under the conditions which existed on some of the roads built. The treatment of these different grades of trap is very material. The lower grade, or the rock of lighter specific gravity, will roll down very easily under the steam roller, while the higher grade, or the heavier rock, breaks

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off on the edges more or less, and in certain cases it does not compact under the action of the roller without special treatment. This special treatment may consist of the application of a little water before the screenings are laid on. It may require a small sprinkling of sand or stone screenings, or a combination of the screenings or sand and water may be necessary. Either one of these, ordinarily, will cause the stone to knit together and permit the roller to complete its work.

There have been conditions where the speaker has felt that the trap rock apparently failed to give the best results, as the breaking of the bond allowed the stone to work loose and stand on the surface. All road builders know that one of the greatest causes of wear on a country highway is the weather, and on some roads the speaker estimates that fully 90% of the loss results from the action of the weather rather than from the traffic. The binding course is blown off or is washed off, and with the harder trap rocks a sufficient quantity of the fine dust is not produced under the wheels of traffic to supply the loss caused by the weather. Under these conditions there is sure to be a loosening of the bond, and a surface on which the stone is more or less exposed. This has been one of the most serious difficulties which the Commission has encountered. There has been a great temptation at times to try some other binding material than the screenings, but up to the present time, on the 200 miles of road which have been built, nothing but the stone screenings has been used during the original construction. On certain country roads, however, when there has been no rain for a long period of time and the rocks have appeared on the roadway, a very thin sprinkling of coarse sharp sand has been used over a narrow strip in the center of the road; that is, theoretically a thin coating of sand. The practical difficulty in the use of the sand, however, is to employ intelligent men to carry on the work by the use of a small quantity only, the tendency being to use too much. For example, in visiting one of the roads a short time since, the speaker found that the whole surface had been covered with 2½ ins., more or less, not of coarse sand, but of fine sand. Unquestionably that would prevent raveling, but not in a manner to give the best results, as the road was unsightly and yielding under the wheel. The Commissioners think that the mere sprinkling of sharp clean sand will accomplish the desired purpose.

To prevent raveling out there are two other methods which have been tried, both of them having been more or less effective. One is to cover the top of the course of stone with a very thin coating of what is termed blue gravel before spreading the screenings. This blue gravel is a natural broken stone of angular fragments. It is bound together with the finer stone dust, and a small, but varying, percentage of clay. The finer fragments of angular stone which will pass a ¼-in. mesh, mixed with the clay and the stone dust, make an excel-

lent binder when spread on the top course of stone in a thin layer (not over ¼ in. thick) and wet, then covered with the screenings and the whole mass rolled. The blue gravel and screenings together make a very hard and elastic surface, which has been found to stand both wet and dry weather perfectly well and which does not allow the surface to ravel. Mr. McClintock

There is one point in connection with the sizing up of the stone to which attention might be called, viz.: On a country road the 1¼-in stone constitutes the surface coat, with the coarse or 2½-in. stone at the bottom. Where the road passes through a village or where it is a heavy-traffic road this order is reversed by placing the 1¼-in. stone at the bottom and the 2½-in. stone at the top. By this method the stones are separated into sizes, and the proper sizes selected for particular uses. Some such method as that just described is made necessary by the fact that in the ordinary process of crushing the stone, there is sure to be a certain percentage of each of these varying sizes. The speaker thinks that in the crushing of ordinary trap rock about 13% of the product is ½-in. stone and finer, and about 61 or 62% of the product is 2½-in. stone, the remainder being the 1¼-in. stone. By putting the stone on as has been described, viz., about 4 ins. of the 2½-in. stone after the rolling, and 2 ins. of the 1¼-in. stone after the rolling, and about ¼ in. to 1 in. of the screenings, the entire product of the crusher will be used.

Fully 50% of the Massachusetts roads have been built of native rock other than trap, the greater part of it being field stone of a mixed quality, such as granite, quartzite, conglomerate, felsite, and a small percentage of the softer rocks. These native rocks have been mostly broken up at a certain stipulated price per ton, varying from 20 to 50 cents, by means of small portable crushers which have been set up by different contractors on the line of work, so that under general conditions it was absolutely essential either to use the whole product of the crusher or else pay for a certain amount of waste.

In the maintenance of the roads, up to the present time, no regular system has been developed. The best effort possible has been made in every case to keep the road in good repair. The principle of perpetual care has been adopted, keeping the roads up to the standard without letting them go to pieces, and they have been repaired entirely by the use of the screenings with possibly the slight sprinkling of sand, which has already been mentioned, to prevent the raveling out.

The cost of maintenance cannot be given at the present time. The cost of the work which was mentioned as being $10 300 per standard mile is distributed over various items, and the grading item alone, that is, the necessary cut and fill to bring the road to a maximum 5% grade, has averaged $1 250 a mile. The outlay for grading on some roads was practically nothing, and on others it has amounted to $12 000 and even $15 000 a mile where it was a mountain road, partly in rock

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and partly in clay, with heavy retaining walls on either side, numerous culverts to remove the surface water from the steep slopes, paved gutters, etc., etc. On these mountain roads, unless the water be removed quickly from the side of the road, great damage might result from a single storm, and the culverts have been built at short intervals to prevent large and high velocities. The sides of the road have been finished out to a width of 24 or 26 ft. Old tree stumps and roots have been taken out, large and loose rocks have been removed from the roadside, and generally from fence to fence the location has been left in good shape, the center constituting a hard, smooth roadway for traffic and pleasure, with the sides pleasant to look upon.

Mr. Budd.

HENRY I. BUDD, Esq.*—In the year 1891 a road law was passed in New Jersey granting State aid to the amount of one-third of the cost of the roads. The proceedings under that law are as follows: Those wishing improved roads petition to the freeholders for them, and, for the peculiar benefits conferred, agree to pay one-tenth of the cost. Then, if the freeholders of the county accept the petition, they order a survey to be made and specifications prepared. If the State Commissioner, to whom these specifications are forwarded, approves them, and the road is built, one-third of the cost is paid by the State, one-tenth by the petitioners, that is, the residents along the line of the road, and the balance, about 57%, by the county. Under that law, in 1891, $20 000 was appropriated, but not a dollar was called for, the opposition to the law being very great, especially on the part of farmers, who claimed that their taxes would be unduly increased. In 1892, $75 000 was appropriated, and only about $21 000 called for. In 1893, $75 000 was appropriated, and about $71 000 called for. In 1894, $75 000 was appropriated, and nearly the whole amount was called for

A mandamus clause in the law compelled freeholders to build roads when petitioned for, and when building began there came from different parts of the State a cry that it was tyrannical and oppressive. Strong petitions and many farmers opposed this clause before the Legislature, and it was eliminated; but the object lesson had been given in different parts of the State, and from that time applications became numerous, even in counties which had opposed the law and opposed the mandamus clause. In 1895, 1896 and 1897, $100 000 was each year appropriated and spent. In the last year even more was spent. Work is being done under a $100 000 appropriation for 1898. The State aid of $100 000 means an expenditure of about $350-000 each year, taking the State, county and individual contributions, which all hinge upon the State law and the acceptance of roads petitioned for by the Commissioner. Under that law about 300 miles have been built and about 300 miles more are petitioned for. Under the first working of the law the roads were rather expensive, as the most

*State Road Commissioner of New Jersey.

economical way to construct them had yet to be learned, and contract- Mr. Budd.
ors had nearly their own way, which resulted in a cost of from $7 000 to $10 000 per mile. After a while stone-crushing plants began to multiply, and a great deal of competition resulted. It was learned that thinner roads were sufficient to bear the traffic, and the cost was reduced to from $6 000 to $7 000 a mile. In 1897 they cost about $5 000 a mile, and in 1898 about $4 000, and two roads 10 ft. wide and 8 ins. deep were built for $3 000 per mile. Omitting a few gravel roads from the 90 miles now being constructed, the cost will be about $4 500 a mile. At first, from 30 to 40 miles of road per year were improved; in 1897, 70 miles. In 1898, about 90 miles are under construction. In Essex County telford roads are the rule, but in other counties pure macadam construction leads. In the former there are large quantities of stone in fences which the farmers are glad to get rid of, and which make an excellent telford foundation. Through this county trap rock ridges are so common that crushers can be established along the line of each road, and thus the road can be covered cheaply with broken stone. It makes little difference in cost whether the roads are 3, 4 or 6 ins. in thickness.

In the southern part of the State 8-in. macadam is the leading depth, there being only one 6-in. road. In the country the roads are built 10 and 12 ft. wide; in the towns, about 16 ft. wide. These widths have been fixed as the limit for State aid; then, if the citizens or the municipalities wish the whole street covered, they do the balance at their own expense, and the extra paving does not enter into the State's calculation of cost. These roads are costing all the way from 23 cents to 70 cents per square yard, and where telford is used, in bad places, the cost reaches 73 cents. The average cost of these roads in 1897 ranged from 50 to 60 cents per square yard.

In the upper part of the State, in Morris and Passaic Counties, roads are built only 4 and 6 ins. deep; consequently their cost, where rock is mined along the road, ranges from 20 to 45 cents per square yard. Trap is the leading rock for construction. Commencing at the Palisades, the trap rock formation, 20 miles wide and 70 miles long, extends the whole width of the State, jutting out at convenient places in each section. The railroads run north and south, east and west through these trap ridges, and consequently the trap can be mined and easily transported to any portion of the State. The southern portion of the State is a vast plain; north of and around Trenton, a glacial drift; south of Trenton, alluvial deposit, once the bed and shore of the ocean, with no stone in the elevations or on the surface; consequently, all stone used has to be imported, and the railroads running through the trap ridges bring the stone to the southern counties of the State at a price almost as low as when transported by rail further north. The railroads seem to have a common price for

Mr. Budd. carrying stone, there being not more than 10 or 15 cents a ton difference between long and short distances, say 20 miles and 70 miles from the trap ridges. The southern and eastern portion of the State is largely a sandy plain, with occasional gravel deposits. In this portion gravel roads have been adopted with good results. Experience here shows that gravel laid upon sand makes a better road than when placed on a hard bottom. The average haul does not exceed a quarter of a mile, so that the cartage is not an important item of the cost. The cost of roads 14 to 16 ft. wide, with 8 ins. of compacted gravel, is from $1 000 to $1 500 a mile. There is now one gravel road 34 miles in length, forming, with a stone road commencing at Camden, a complete highway 64 miles long between Camden and Atlantic City, on which carriages or bicycles can travel easily and rapidly. As many as 3 000 bicycles a day pass over it, during the summer season.

The speaker's plan has been to create, as rapidly as possible, continuous highways. When the law first went into operation a little piece of road was applied for here and another there, with no connection between them; and, consequently, there was no continuity. A system of continuous avenues has now been adopted, and is very nearly completed from Atlantic City in the southern portion of the State to Jersey City, and from Jersey City to the extreme western boundaries of Morris and Passaic counties. A great many lateral roads leading into these avenues and to different county seats and important towns have also been improved. In the western section of the State another system is being built which is almost parallel with the first, so that in a few years there will be two continuous lines north and south through the State, besides many lateral roads leading into them from the east and west.

The State Aid Act at first was extremely unpopular with the farmers, and if it had not been for the wheelmen the law would probably have been a failure. The wheelmen persuaded the Legislature, that it was to the interest of the State to vote for good roads; the farmers were very strong in opposition. Now, the wheelmen are not using much effort, and the farmers are the pleaders and workers. In some parts of New Jersey a man cannot now be elected to the Legislature unless he is an advocate of these roads. It seems to be a matter of history that farmers are the earliest opponents of road improvements, and later the most ardent advocates. The speaker had been before committees of the New York Legislature, when the committee rooms were crowded with hundreds of farmers protesting that the contemplated law would ruin them, although it was developed that the towns paid 88% of the State taxes. It was also shown there that under the law some of the larger farms would not be taxed over $4 or $5 a year.

The reason that farmers in New Jersey are becoming warm advocates of the law is shown by the following example. Camden and Glouces-

ter counties are two great farming districts, in which immense amounts of vegetables and fruits are raised and hauled to the Philadelphia markets. Before the advent of stone roads, the farmers had to drag their produce from 10 to 15 miles through heavy sand. It was with difficulty that 30 to 40 baskets of truck could be taken in one load. The size of the wagons has been increased, and they now carry from 130 to 160 baskets. Formerly a great deal of produce was shipped by small boats on the numerous creeks which intersect that section of the country and are tributary to the Delaware River; the freights, cartage, etc., amounting to from 6 to 8 cents per basket. The farmer now carts his own produce to market, and saves from $10 to $12 a day. If five loads a week are carted, the saving is from $50 to $60, and, in addition, the produce is delivered to the customer in a fresher condition than when sent by boat, where three handlings are necessary. It can be readily seen that under these conditions a farming community becomes an ardent advocate of good roads. Mr. Budd.

Gneiss and granite are the leading rocks in the northwestern portion of the State, and here the practice is to use this native rock instead of trap, thus avoiding the cost of transporting the latter. These roads are consequently very cheap, and while they do not last as well as those made of trap, they can be frequently resurfaced at small cost.

N. P. Lewis, M. Am. Soc. C. E.—The speaker will simply attempt to outline the most important points in road construction. Mr. Lewis.

The idea that hard, smooth roadways are essential in the streets of large towns, but are a luxury beyond reach in rural districts, while it has been persistent, is gradually giving place to the conviction that all roads can as well be good as bad, and that the money used in improving them is profitably expended.

Many efforts have been made to express in dollars and cents the cost of bad roads, and the figures deduced have been astounding.

In Virginia, for instance (which, it must be admitted, is not famous for good roads), it is stated that the interest on depreciation of land, the additional cost and time lost in hauling, and the annual depreciation of vehicles, horses and mules, amount to $4 275 000, which is nearly $2 500 000 more than the total tax collected in the State.

The Secretary of the National Farmers' Congress has estimated that the needless cost of moving farm products in the United States,—*i. e.*, the cost beyond what it should be.—is $600 000 000 a year. Professor Latta, of Purdue University, basing his estimates on the conditions in Indiana, concludes that the difference between good and bad roads is 78 cents per acre of farm land, or $500 000 000 for the entire United States.

The fact that poor roads are the source of great expense has been so well demonstrated by good-roads leagues and other kindred associations that it need not be enlarged upon. Some States or counties

Mr. Lewis. have, by legislation, taken the matter up, and are transforming their "streaks of mud or dust" into hard, smooth roads over which far greater loads can be hauled with much less power. An enthusiasm on the subject has developed that will soon break down indifference and prejudice, and result in the permanent betterment of the roads. These attempts at improvement have sometimes been very crude. In Wisconsin, shingle sawdust, 8 ins. or 10 ins. deep, and covered with a few inches of sand, has given good results for four or five years. In prairie or alluvial districts where gravel or other coarse material is not easily available, and where stone is almost unknown, a few inches of brush or straw covered with earth has given good drainage and fair roads. Gravel mixed with a little clay has made excellent roads in localities where such material is readily obtained

This discussion, however, should be confined to road building, not road mending, as the operations referred to may more properly be described, and road building is scarcely the application of makeshift methods, but the permanent construction of a road according to the best practice. Not that the same kind of road should be built under all conditions, but in this, as in other engineering work, the construction should be governed by the use to which it will be put, and the resources which are available to pay for it. Stone roads only can be considered permanent. The building of such roads can begin before the making of a contract for the actual work. The ultimate improvement by macadamizing all important roads should be kept in mind, and such work as is done from season to season should be determined accordingly. It is assumed, of course, that all roads have some kind of supervision, and that there is a competent officer, whether County Engineer, Superintendent or Commissioner, who is charged with the present care and planning for future improvements of the highways. (The speaker is aware that this is a bold assumption.) The dirt roads should, therefore, be well drained, both by surface ditching and under-draining where the soil is heavy. This will greatly improve the dirt road, and is an essential of permanent work. Hills can be cut down, and low places raised, gradients being reduced, and in many cases alignment can be improved before a permanent improvement is authorized; but it should be kept always in view. Such supervision is hard to obtain. The general impression is that an engineer is not needed until profile, plan and specifications for macadamizing are to be made. It will doubtless require mandatory legislation before intelligent technical men will be placed and retained in such positions.

As to the character of roads to be built. If near a large town, where the traffic will be considerable, the road must be of generous width, 20, 25 or even 30 ft. for the metaled portion. For country roads, where the traffic is less, this would be a waste of space and

material, and a width sufficient for two vehicles to pass is enough— say 12 ft. Similar considerations will govern the selection of material. Where the traffic is heavy it will be wise economy to secure the hardest, toughest stone available, even though a softer stone can be obtained near at hand at less expense. The cost of rolling a trap rock road will be greater than for a limestone road, but if the traffic is sufficiently heavy a higher price for the tougher material, as well as increased cost of rolling, will be justified by the more permanent results obtained. Mr. Lewis.

In cases where the traffic is light, good limestone will make a most satisfactory road, and one which can be more economically repaired than any other. Dependence will often have to be placed, however, upon the local stone, unless, as already remarked, the traffic is very heavy, when the toughest and best material should be obtained even at a considerably greater cost. Field stones are usually tough, and make an excellent road metal, but are apt to be of variable hardness.

As to the foundation: Drainage is a *sine qua non*. This is a very simple matter on Long Island, where the soil is nearly always gravelly, and surface water soaks away very rapidly. Side ditching and underdraining must be done, if necessary, to secure a dry roadbed. Once drained it can be rolled, and the character of the soil is, in the speaker's judgment, a matter of little consequence, except that if it is a loose, clean sand, the addition of a little earth or loam will be necessary before it can be rolled. After a thorough rolling with a steam roller of moderate weight, the roadbed is ready for the stone. The aversion of Macadam to a foundation of large stone was very strong. He said:

"The roads can never be rendered perfectly secure until the following principles be fully understood, admitted, and acted upon, viz., that it is the native soil which really supports the weight of traffic; that while it is preserved in a dry state it will carry any weight without sinking, and that it does in fact carry the road and the carriages also; that this native soil must be previously made quite dry, and a covering impenetrable to rain must then be placed over it in that dry state; that the thickness of a road should only be regulated by the quantity of material necessary to form such impervious covering, and never by any reference to its own power of carrying weight.

"The erroneous opinion so long acted upon and so tenaciously adhered to, that by placing a large quantity of stone under the roads, a remedy will be found for the sinking into wet clay or other soft soil, or, in other words, that a road may be made sufficiently strong artificially to carry heavy carriages, though the subsoil be in a wet state, and by such means to avert the inconvenience of the natural soil receiving water from rain or other causes, has produced most of the defects of the roads of Great Britain.

"At one time I had formed the opinion that this practice was only a useless expense, but experience has convinced me that it is likewise positively injurious."

Mr. Lewis. The following evidence given by him before a Parliamentary committee shows still more clearly what views he held on the subject :

"I should think that 10 ins. of well-consolidated material is equal to carry anything.

"Q. That is, provided the substratum is sound?

"A. No, I should not care whether the substratum was soft or hard; I should rather prefer a soft one to a hard one.

"Q. You don't mean you would prefer a bog?

"A. If it was not such a bog as would not allow a man to walk over I should prefer it. * * * I think when a road is placed on a hard substratum, such as rock, the road wears much sooner than when placed on a soft substratum.

"Q. But must not the draught of a carriage be much greater on a road which has a very soft foundation than over one which is of a rocky foundation?

"A. I think the difference would be very little indeed, because the yield of a good road on a soft foundation is not perceptible."

Of course these extreme views as to the unimportance of foundation would not be endorsed by engineers of to-day.

Some of the finest specimens of road making are those laid on a telford foundation—notably, the roads in Central Park and some of those in Prospect Park. It would not be prudent to say how thick they are, and they are perfectly drained, but their cost must have been very great. Assuming that a road is to be maintained after construction, why make it more than 8 ins., or, in many cases, 6 ins. thick? A road of this thickness made with two courses of broken stone will certainly sustain any load which it can be called upon to carry. The real value of a road, per mile, increases with its length, not with its depth, and the public money can best be expended by increasing the former.

In building country highways, city lots upon which to assess the cost are not available. With farm lands within two hours' ride of New York City, selling for from $2 to $20 per acre, in addition to the cost of the buildings upon them, it is not practicable to lay telford foundations and put on the broken stone by the foot. Macadamized roads 8 ins. thick and 12 ft. wide can doubtless be built in country districts, where material can be obtained within a moderate distance, for $5 000 per mile, and in many places for $3 500 to $4 000 per mile. General Roy Stone stated before the Senate and Assembly Committees at Albany that $1 000 per mile would build good roads in New York State, except in the vicinity of large towns, but he must have had in mind something other than what is commonly known as a macadamized road. The method of building, the size of stone, the rolling, etc., are so well known, and so much has been written upon the subject, that it is scarcely necessary to refer to them before this Society, except to promote discussion, for there are still some differences of opinion. Some engineers, faithful disciples of Macadam, still prefer stone as nearly as possible uniform in size, entirely free from chips

and stone dust, though they would scarcely specify, as did Macadam, that "The stone should be broken by men sitting on their haunches and striking it with a small hammer." This might be done within prison walls, by the State, but scarcely under other circumstances. Stones varying in size from 2 ins. to $\frac{3}{4}$ in. will have fewer voids, and will form a more solid roadway, with far less rolling than in the case of those of uniform size. When limestone is used, stones varying between the limits named will, with the addition of a few screenings of the same material, make a smooth, hard road, with comparatively little rolling, and one which will be very satisfactory under light or ordinary traffic, except in dry weather, when it will be extremely dusty. Efforts have been made to build a good road of trap rock, without the addition of any fine material, but the speaker believes they have been unsuccessful. Persistent rolling with very heavy rollers, preceded by a sprinkling cart, has reduced the size of the surface stone, but there has been no cementing of the surface material. The addition of trap-rock screenings and flour resulted in a great improvement. This flour is largely quarry sweepings (or was before the demand for trap became as great as it is at present), and the speaker is convinced that the more foreign matter the flour contains, the more satisfactory are the results. Specifications recently prepared provide for a binding material for trap-rock roads, 60% of which shall consist of trap-rock screenings and flour, and 40% of selected coarse sand or fine gravel, preferably mixed with a little clay or hard-pan. Mr. Lewis.

Limestone screenings as a filler with trap rock give excellent results, though if the road is to be subjected to very heavy traffic the trap screenings mixed with sand would probably be better. The use of the Roa Hook gravel from the Hudson River near Peekskill has given admirable results in binding roads, and in patching up the surface, and it makes a beautiful surface for riding, but it is short-lived and expensive.

If the State is going into the road-building business, there is a source of economy which may be taken advantage of. There are about 1 000 able-bodied men in Sing Sing Prison who might very well prepare material for the roads. In California it is said that the cost of furnishing road material by the State has been reduced to about 25 cents a ton. There, a vein of excellent trap rock runs through the prison grounds, and they have set the prisoners breaking it. The railroads have given favorable rates, and it is said they are laying stone along the roads at about the price at which it can be produced at ordinary quarries.

The important points in road building, as they appeal to the speaker, may be summarized as follows: The anticipation of the ultimate, substantial improvement of every road and the determination of the work which is to be done with that in view; the rectification

Mr. Lewis. of grades where possible, bearing in mind that the loads which can be hauled over any road are determined by the steepest gradient on the road; the proportioning of the width and depth of the road in accordance with the density and the volume of the traffic which it will have to sustain; a thorough and conscientious drainage of the foundation where the material requires artificial drainage; the selection of the toughest material which can possibly be secured for the money available; thorough rolling, with judiciously selected binding material, and, above all, the care and maintenance of the road when complete; and to these might be added constant supervision by a trained technical man, whose term of office shall not be one or two years, but who shall be kept there so long that the State or the county may have the benefit of his experience.

Mr. Tomkins. CALVIN TOMKINS, Assoc. Am. Soc. C. E.—About the year 1865 the Central Park roads were macadamized with chips from quarries near New York. These chips consisted of the waste material from the quarries, which had not been put through crushers. From that time down to about 1890, generally speaking, roads were built in any way by anybody. County commissioners usually built the roads, and very little attention was given as to how they should be constructed. Stone was bought, carted to the road, distributed, and allowed to wear down under the travel. Engineers, as far as they did have charge of road building, treated questions that came before them diversely, and there was no uniformity of practice. Since the early nineties conditions have changed very much. There exists now a general agreement as regards the practice of road-making, and the art has drifted more into the control of engineers and county commissioners, and politicians do less road building. There is now a skilled body of contractors willing to build roads, and as a consequence much better roads are built than were constructed formerly. There is one point, however, to which the speaker would call attention, where all that could be done has not been accomplished. Road building is now in the hands of engineers, but it has not as yet attained the position of a fine art. Almost any engineer accustomed to road work will build a good road; but the difference in the economies that can be effected in roads as constructed by some engineers and as constructed by other engineers is still very great. These nice economies should be discussed, rather than questions of general practice, which already are well established. The question of stone sizes, mentioned by Mr. McClintock, is a practical one. It is necessary to use all the product from the crushers if roads are to be constructed economically; otherwise the large stone, to get it down to a uniform size, must be recrushed, and the small stone will be wasted.

Another point in which nice questions of economy occur is in connection with the subject of thick or thin roads. As far as the speaker's

Mr. Tomkins.

experience goes the art of road building consists in making a thin road go just as far as possible. When bad places are encountered, over a morass or on a clay bottom, it may be necessary to put down a thick piece of road-bed such as will distribute a heavy load over a large surface before it reaches the limit of the bearing strength of the road. It is necessary to put down thick roads where they are subject to heavy, urban travel. It is not necessary, however, to build even 8-in. roads in country districts generally, particularly where there is a sandy bottom and the drainage is easily taken care of. If a little more is spent for drainage, where the bottoms are not so good, a thin road can be made to do as well as a thick one, and money will be saved. Such questions in road building are new and interesting. All the suggestions that have been made in this discussion are safe, so far as experience leads the speaker to judge of them. He thinks that it would be safe to go farther, in some instances. The principal consideration, which should be borne in mind, is: How far can these roads be safely constructed ? Is it not also worth while sometimes to make an experiment, when it does not cost much, in order to see what it is possible to do in the direction of making the minimum amount of money build the maximum amount of road ? As Mr. Lewis truly said, a road is valuable to the people who use it, not according to its thickness, but according to its length and width. In this connection the speaker does not believe—and this is the only technical point he wishes to make—that enough attention has been given to the question of consolidating roads into compact, almost monolithic, masses of stone. A road which will shed the water to the sides and keep its base dry conforms to Macadam's idea of what a road should be—simply a wearing surface on top of a dry solid underpinning of any character. If this base is kept dry by protecting it on the sides with ditches and drains, and by constituting the road-bed surface virtually a roof to shed the rain, the road is just as effective from an engineering point of view as a sound tooth, which simply consists of a hard surface upon a soft base. In order to accomplish this it is desirable to consider first the question of filling and thoroughly rolling the road-bed; and, secondly, of cementing the pieces of stone together and keeping them in that solidly set condition regardless of wet or dry or windy weather.

The question of suitable materials for these purposes is most important. Trap rock is undoubtedly the densest and hardest material which can be used, but it lacks binding properties, and, when used by itself in thin roads, particularly if not carefully rolled, is likely to ravel out and go to pieces.

Even when thin granite or trap-rock roads have been carefully consolidated during construction, they are likely to go to pieces in dry, windy weather, or when subjected to unusually heavy loads, or when the soil becomes wet and yielding beneath them.

Mr. Tomkins. This question of maintaining the surface of thick granite or trap-rock roads, and of maintaining the body of thin granite or trap-rock roads, is a serious problem which confronts engineers.

In the speaker's estimation, thin roads subjected to light travel can be built more cheaply and maintained more effectively when constructed of other material than trap rock or granite, since it is possible to cement such roads together, when it is not possible to do this with the harder stone by itself.

It is possible, however, to bind a granite or trap-rock road together with cementitious limestone screenings in such a way as to bring into play the maximum efficiency of both stones—the wearing qualities of the trap and granite, and the cementing qualities of the limestone. In such roads, when properly consolidated during construction, the pieces of harder stone do not become separated from the mass, and the surface itself remains smooth, the wear coming upon the surfaces of the harder stones, which are ground flat, and which do not project in a rough, knobby manner, as is likely to be the case when the siliceous binder is washed out of roads constructed of siliceous stone.

Many examples of such trap-rock and granite roads bound together with cementitious limestone can be seen in the immediate vicinity of New York City, some of which have been subjected to travel for a long time, and give evidence of unusual wearing qualities, besides affording a smooth surface.

This question of binding thick and thin roads, however, is only an instance of the general proposition which the speaker wishes to make, namely, that the present interest, which this road-making question has for engineers, commissioners, tax payers, and others, will be found in the consideration of economies to be practiced in construction and maintenance, rather than in the general principles of construction itself, which principles are now pretty well established.

An engineer who can build roads for $4 000 a mile as effectively as another engineer whose specifications make their cost $8 000 a mile, will come to be considered by the community twice as good a man as the latter.

Mr. Roullier. G. A. Roullier, M. Am. Soc. C. E.—The cost of road construction is a question so extremely important that it requires special consideration. Upon it depends the expansion of good road work throughout the country. Probably the principal item in which economy can be practiced—because it is about the only flexible item encountered in road construction, the majority of the items being fixed—is the thickness of the road-bed. Still, the speaker believes this is the very item on which engineers disagree the most.

The question is, how thin can roads be safely built? It has not yet been positively ascertained, as far as the speaker knows. Having made some experiments in that special direction he would like to sug-

gest this principle for consideration, so that a minimum thickness may be arrived at, *i. e.*: A road-bed having been constructed strong enough to safely carry the traffic that it is intended for, the condition of the surface becomes absolutely independent of the thickness. The condition of the surface will be dependent on suitable design and proportion, good workmanship and intelligent maintenance. By this is meant that, if the thickness of the road-bed has been so proportioned that it will carry the traffic without being cut through, and a certain factor of safety added to that thickness, further increase will certainly not insure a better surface. Hence, why should a certain limit of thickness be exceeded, providing that limit can be determined? Of course, in thin road construction—that is, construction without artificial foundation—a careful distinction must be made between roads intended for light suburban traffic and those designed for main thoroughfares. Mr. Roullier.

In the construction of thin roads the speaker must differ from Mr. Owen in the proposition as to the binding or filling material. The speaker has found that in building thin roads it is almost impossible to get successful work with a soft binding material. It is absolutely necessary to use a binding material that is hard and coarse, so as to prevent any possibility of motion in the mass. If motion occurs in a thin road-bed, failure is bound to follow. In the filling of these roads, the speaker would suggest that sand and coarse screenings will, as a rule, give the best result. He has tried almost every material, and believes that a great many of the failures in thin roads have been caused through the use of a soft filler. In filling these roads he has had considerable success by adding to the filling of sand and trap-rock screenings a slight amount of clay in some cases, in others limestone dust, adding about 30% in each instance. The raveling in those cases was materially reduced, and the road-beds could be left exposed to the weather without detrimental effect.

It is almost impossible to keep roads surfaced in localities where there is heavy traffic, but where the traffic is not too dense or too heavy a very good covering can be made by simply using the dust of the crusher with a very slight amount of clay; the speaker has seen it tried in some places quite successfully. He thinks that any one who will give personal attention to it for a short time will find that on such roads a covering can be placed which will remain there and give but little trouble.

E. W. Harrison, M. Am. Soc. C. E.—On the Hudson County Boulevard, following the lead set by Mr. Owen in Essex, N. J., about 400 000 sq. yds. of telford macadam have been laid in the last five years on roads whose conditions were those of city streets. Heavy traffic had to be provided for, and also the sewerage. The drainage had to be arranged so as to connect with the sewers already con- Mr. Harrison.

Mr. Harrison. structed by different municipalities, and with a view to future construction. Under the Act, no sewers could be built except on the line of the Boulevard. The road is theoretically 12 ins. deep, but practically about 14 ins. There are 8 ins. of telford, of ordinary specification, all trap rock, and 4 ins. of macadam. It is endeavored to have about 2 ins. to 2½ ins. of stone which will pass through a 2½-in. ring. On top of that is put the 1½-in. course, and the surface is brought up with coarse screenings about ½ to 1 in. above the finished grade, using a great deal of flour and wetting the road all the time and keeping a roller on it.

When work on the road was begun the cry of the contractors was, "You cannot expect to bind trap rock with water." In the first 8 miles built there is not a spoonful of anything but trap rock, but a great deal of rolling was done and a great deal of water used. This section is standing much better than any other portion of the road.

On the upper part of the road the water had to be procured from a private corporation, and was very expensive. The road was built in summer. The water evaporated about as fast as it went on, and in this place the speaker allowed the use of a slight powdering of clay between the 2½-in. and 1½-in. layers. The clay was needed to hold the water a few seconds only while the roller was going over the road. There has been no trouble from raveling. Of course, this road is sprinkled. In a country road, lime or clay might be used, which might prevent the raveling. The greatest trouble is to keep the road free from the dirt of unpaved streets, from which there comes a great deal of wash.

A wagon coming through those unpaved streets loads its wheels with mud, and the moment the horse strikes the telford he begins to trot and the mud drops on the road. Some of the contractors claim that this has helped to consolidate the road, and there are people in Jersey City who claim that it is a good top dressing. The greatest difficulty experienced in building the road has been to accommodate the top surface to the use of bicycles, trotters, riding horses and heavy teams, and the speaker has come to the conclusion that it cannot be done so that everyone will be satisfied. The speaker believes in bringing the traffic right down on the stone, but if all the top dressing is stripped from the road so as to bring the heavy traffic on the stone, the wheelmen object.

In this Boulevard there is one peculiarity which has often been criticised. On the fourteen miles from Bergen Point to the county line, the middle of the road is gravel. That was a radical experiment. It was desired to get as wide a road as possible with the money available, and at least $1 000 000 had to be spent for right of way. Forty houses were bought and 400 were moved, and almost the whole right of way had to be condemned. Bridges over the railroad cuts cost $130 000, and it was found that the road

could not be built at the prices then ruling and give the full 60 ft. width of macadam. The problem was whether the example of Essex in putting 18 or 20 ft. of macadam in the center with earth wings should be followed, or whether the earth should be placed in the center and the macadam at the sides. Just before that time the late Chas. B. Brush had built a short piece of road in the upper part of the county, which was intended to have a trolley in the center. He had put macadam and telford on the sides, and left 15 ft. in the center for the trolley track. This road had been in existence about two years, and the center was perfectly drained by the telford, was dry in the spring and was used in preference to the stone road for fast driving. The speaker took that idea and enlarged upon it a little. A 15-ft. strip was laid out in the center of the road, and after preparing a subgrade 4 ins. below the finished grade, or at the elevation of the top of the telford stone, a 4-in. layer of Shark River gravel was placed on the southern 8 miles of the road. The upper 6 miles has 4 ins. of Roa Hook gravel. The Shark River gravel has now been in place 3 years, and has been worn down 1¼ ins. In the spring the gravel center, with the wings of telford going down a foot below, dries up quicker than the macadam. Gravel dries very fast, and the speaker has a great deal of faith in the South Jersey gravel roads, provided they are well drained. It is a very great mistake to haul trap rock to Cape May, where there is good gravel. Mr. Harrison.

There is one other point in regard to which the speaker has not heard, except in the Massachusetts case. In constructing this road the surface was first shaped and rolled hard; then the telford was put down, and after breaking off the points and wedging it well, the steam roller was put right on top of the rough telford. Two Harrisburg rollers and two English rollers were used. Those in charge of the English rollers went right ahead, but those having the Harrisburg rollers were at first afraid it would smash the rollers. This rolling is a very great success, because the bottom telford is put down so that it never comes up again, and if there is any weak point it is at once discovered. The real test of the telford was the steam roller. When the contractor was willing to have his telford rolled and made a generally smooth surface, the speaker was satisfied that the other course should go on. Loose chips were not allowed on top of the telford, although the speaker does not know whether they would have done any harm or not; but he had an idea that in rolling they might work up through the broken stone. The contractors all wished to throw chips on and make it easier for the rollers. The telford was rolled; the first course was rolled, also the 1½-in. course; screenings were sprinkled on it, and it was finally rolled with water until the surface puddled.

The speaker has found by the mileage of the rollers that every inch

Mr. Harrison. of the road has been gone over from 100 to 115 times, and he thinks it has paid and has been the making of the road. Since the road was finished it has been in the hands of the freeholders for three or four years. The great problem is its management and care. The speaker's idea is that a great many men can be found who can build a good road, but the hardest problem is to find one who can take care of it after it is built. Most people think that when a road is built it will last forever; but there must be a certain percentage of material put on it every year, and put on in the proper way. In regard to one part of the Boulevard, after it was finished a complaint was made by the inspector that for about a mile the macadam was too thin. This portion was very finely surfaced, bound in nicely, and was below grade and a little thin, and, without picking the surface, 1½-in. stone with screenings was put on to bring it up. It was rolled thoroughly, and that portion of the road to-day is about as fine as any other in the whole 20 miles.

Mr. McLaughlin. J. J. McLAUGHLIN, M. Am. Soc. C. E.—There are in Queens County about 800 miles of macadam roads and streets which have cost about $10 000 000. Of these, 335 miles are macadam roads built to carry the traffic of Long Island farmers. There are more than 3 000 wagons running to market every day for very nearly six months in the year. Each weighs when loaded between 10 000 and 11 000 lbs. The wagon itself as it stands weighs 2 600 lbs.; 3-in. tires are used. For this traffic 4-in. roads are not built. The heaviest roads are 8 ins. thick in the center and 6 ins. at the sides. There are now 175 miles of these roads under construction. As far as the sustaining power of a thin road is concerned, the speaker would like to corroborate what Mr. Roullier has said, and can give a good example of the application of his theory. In the village of Jamaica, in 1897, there was a stretch of street about ¾ mile long that paralleled two roads then being improved. The work was done in the spring of 1897 after a sewer had been laid in the same street. It was built with 4 ins. of stone spread loosely. The stone was measured by blocks, and was spread 4 ins. thick, loosely, and then rolled. From actual count there were from 80 to 100 of the heavy loads just mentioned per day for over three months running over this piece of road, and in only one case, where there was some careless work over a sewer trench, was there any material sign of wear, and in no place a break. There was not a square yard of the street broken, and it carried these wagons.

In consideration of the fact that so much has already been said about sizes of stone and methods of construction, very little which would be of any material interest can be added. The speaker, however, would like to back up Mr. Harrison's assertion, even though the discussion of maintenance is to be debarred, that a road may be built poorly, but if there is an adequate system of maintenance put right behind the construction, the road can be saved and made very good.

In Queens County there are some roads known quite widely as being among the best bicycle roads, but which were poor when built. They were made good roads by efficient maintenance. Queens County has the best system of maintenance in vogue in the vicinity of New York City, and it is considered of the greatest importance. After a road is well constructed it is immediately passed into the hands of the parties who maintain it. Mr. McLaughlin.

The method used is practically as follows: The roads are divided into sections; the length of a section depends on the location and the character of the work, and averages about 12 miles. Each section is in charge of a foreman who keeps a small gang of men, generally two and in some instances as many as four, continuously employed. These men keep the stone work slightly covered with a mixture of gravel and loam, mend slight depressions, keep the gutters cleared up, and the wings or earth shoulders free from grass and weeds. These earth wings are ploughed and reformed when necessary, in order to provide earth roads and good drainage. The wings are generally wide enough to allow of the passage of wagons on either side of the stone work.

In addition to the foreman, there is a superintendent who lays out the work in detail and generally oversees the operations. This was formerly the system throughout the county and is still used in the eastern portions. The work in the borough towns has been let by contract. Contract maintenance does not appear to be a success.

The county owns its own steam rollers, sprinkling carts and machinery. The system has proved very efficient and at the same time economical.

GEORGE W. TILLSON, M. Am. Soc. C. E.—In the construction of a macadam road there seems to be more opportunity for the engineer to show his good sense and ingenuity than in that of almost any other kind of pavement. If a street is paved with either asphalt or stone, certain conditions must be met. The asphalt must be of about the same thickness, and the stone blocks of about the same size. By varying the foundation according to the traffic, the expense may be increased or decreased, but in the main the engineer is bound to general conditions. With macadam, when the amount of traffic which the road must stand is known, it should be possible to construct a pavement that will meet the requirements very nearly. The three things which the engineer must study, and which will govern the expense materially, are the character of the stone to be used, and the thickness and width of the roadway. The stone selected need not necessarily be absolutely the best, but should be the best to meet the special conditions. Of course, it is understood that trap rock will stand more wear than any other material used in the vicinity of New York City, but in a great many cases it is better, in the long run, to use local stone which is not quite as good. That is, it will be cheaper to use a stone Mr. Tillson.

Mr. Tillson. that can be obtained at a small expense, and repair the road more frequently, than to take a material whose first cost is greater. On account of its hardness, trap rock is very difficult to bind; and, conversely, a softer material binds more easily and more quickly. Another disadvantage of trap rock is that when broken it is so far from being cubical. Most of it is flat, and, consequently, the size used for the upper course is often very difficult to bind. For streets or roads where the traffic is light it is better to use a softer stone, such as limestone, that will bind quickly and give a smooth road, than to use trap which requires heavy traffic to keep it in good shape, unless the road is remarkably well made. The binding material used with the trap is apt to wear out and be blown away, leaving the surface of the road in such a condition that in passing over it the wheels of a vehicle jump from stone to stone instead of bearing continuously on the surface.

The speaker has in mind a road that was built seven or eight years ago, of which a portion, at least, is of limestone, which has had almost no attention in the way of repairs. About three years ago this road was extended, trap rock being used. For the first year or two, when the surface was covered with Roa Hook gravel, it was almost an ideal road for either driving or wheeling. During the summer of 1898, however, no attention was paid to the surface, and now in passing over it the wheels jump from stone to stone. For that reason when the travel is to be light, and the road pleasant for riding or driving, especially in these times of bicycling, it is better to build the road of limestone than trap, although the limestone will wear out sooner; on exactly the same principle that one buys a calfskin shoe rather than a cowhide boot.

After the engineer has decided on his stone, he must determine on the width of the roadway. If intended only for travel continuously in one direction, it should not be wider than is economical for that purpose. If two lines of travel uninterrupted are to be provided for, the economical width for this purpose must be determined. Two trucks with 5-ft. width of wheel base, and 9-ft. width of load can pass on a 16-ft. roadway with a clearance of 1 ft., assuming the outer wheels of each to go within 6 ins. of the edge of the macadam; and it is seldom that such a necessity occurs on a country road. If one truck is not loaded it can turn out without difficulty. It seems, therefore, a waste of material to build a country road more than 16 ft., and in some instances more than 12 ft., wide.

A broken stone road, as well as a pavement, is made up of two parts, the foundation and the wearing surface. In determining the thickness of the foundation, the engineer should be governed by the weight of traffic that is to come upon the road, and make it strong enough to sustain that traffic and no more. It is as much the business of the engineer to avoid making anything too strong as it is to avoid

making it too weak. He makes almost as great an error if he constructs a road, or any other structure, costing 50% more than it should, as if he made it so weak as to necessitate an extra expenditure of 50% to make it good. The foundation should be made of a material which will not decay under the action of the weather, and which will be good and solid under ordinary treatment. If this is accomplished, it does not make any difference of what the bottom course is made. Mr. Tillson.

In determining the thickness of the wearing surface, the engineer must find out how much that surface will wear, and how much the surface can be permitted to wear without allowing the road to get too rough, and then make the thickness a little more than that permissible wear. By that is meant that if a road, after it has worn, say 3 ins., has worn so unequally that it must be entirely resurfaced, it would be a waste of material to make that wearing surface much over 3 ins. in thickness—say, make it 4 ins. If it is made 5 or 6 ins. thick, there is a thickness of 2 or 3 ins. below the available wear which is of no benefit at all and is waste.

After the wearing surface has been put on, comes its binding, which, in the speaker's opinion, is the most important part of road construction. The great trouble with many, or perhaps most, macadam roads is that they do not receive sufficient rolling. It is very common for a contractor to want to consolidate the upper part, perhaps the upper inch, of his wearing surface without any regard to the lower, so that only the surface presented by the road at the time it is finished is good. A great deal of care is necessary to prevent his doing this, or, if the road is being built by day labor, for the engineer to accomplish the other result, *i. e.*, to fill all the voids between the stones so compactly as to make the wearing surface one homogeneous and waterproof mass. The stone ordinarily used for this service, approximating what is generally called 1½-in. stone, has about 50% voids, and under the roller perhaps will compress one-half of that, leaving about 25% to be filled with the binder. The speaker has had some experience with different kinds of binders for trap-rock roads, and does not see why it is not proper to use any material that will bind trap rock securely and keep it bound. The specifications generally call for the road to be bound with the same material that forms the surface. On one road of trap rock the speaker used trap screenings, and it took a very large amount of rolling to consolidate it. On one end of the road, for about a quarter of a mile, a mixture was used, consisting of perhaps 25 or 30% sand, and the balance trap-rock screenings. That portion of the road was consolidated in about a quarter of the time that would have been required had trap screenings alone been used. A firm, smooth surface was obtained, and, although it has not been down more than six months, it has not shown any such signs of ravelling or going to pieces as the part covered with screenings only.

Mr. Tillson. In working trap rock the speaker found it necessary to use practically the method described by Mr. Cudworth, *i. e.*, to keep rolling and sprinkling the screenings at the same time. After the interstices of the stone are filled completely, if a substance that is practically all flour be added before the sprinkling and rolling are discontinued, a very much better result will be obtained, because unless a sort of a paste or mortar can be brought to the surface, it is almost impossible to get the trap rock solid.

The amount of rolling required for different roads is quite variable, and is governed by a great many conditions. In the reports of the City of Glasgow for the years 1896 and 1897, it is stated that something over 300 000 sq. yds. of road were kept in repair for those two years. The amount of stone used, as nearly as the speaker could estimate it, averaged about 3 ins. over the entire surface, and the amount of rolling on that varied from 200 to 2 200 sq. yds. per day. The amount of rolling per day on each street is given. Of course it is pretty hard to tell just why the amount of rolling should be varied on practically the same kind of work. The total cost of the repairs averaged about 12 cents per square yard over the entire surface.

There is another point in rolling, about which the speaker has never been able to get any satisfactory information, and that is the different effects of rolling at different speeds of the rollers. The French in some cases speak of rolling so as to get a certain ton-mile per square yard, ranging from .4 to .6 ton-mile per square yard. Taking this for a standard, if the speed of a roller is increased from 4 to 6 miles an hour, its efficiency is increased directly 50 per cent. The speaker, however, does not think that a roller will do anything like 50% more work if the speed is increased 50 per cent. To consider it the other way, as a matter of time, will a roller moving at the rate of 2 miles an hour, do as much work as it will at the rate of 4 miles an hour? The speaker does not believe it will. If not, what is the difference? By increasing the speed the efficiency of the roller is increased, but by what amount the speaker has not been able to learn. Experiments to determine the relative efficiencies of different rollers at different speeds would be of great value. The speaker had an account carefully kept of the amount of rolling done on one of the roads before mentioned. In the top there were about 18 000 sq. yds. The lower course consisted of 4 ins. of limestone and the upper course of 4 ins. of trap rock bound with trap screenings; and the area rolled per day averaged almost exactly 200 sq. yds., including both courses.

In the summer of 1898 the speaker rode over a road in Morris County, New Jersey, which seemed particularly good. He afterward learned from the engineer in charge, that the road was 4 ins. thick, that it was constructed entirely of trap rock, binding material and all, and had been down for four years. The speaker saw

it at the end of a dry spell of four weeks, and there was no sign of raveling or other faults. The engineer said the road was rolled in two courses, the lower course 2½ ins. and the upper 1½ ins. thick, and that each course was rolled absolutely solid. He said that a road of that character, 12 ft. wide, could be built at the rate of 100 to 150 ft. per day. That would be from 130 to 200 sq. yds. per day, and the speaker does not believe that a trap-rock road can be put down very much faster than that, and at the same time receive the necessary rolling. If Mr. Harrison consolidated the Hudson County Boulevard by rolling it 110 times he did well. Mr. Tillson.

CHARLES H. GRAHAM, M. Am. Soc. C. E.—Referring to Mr. Tillson's statement that limestone roads are more pleasant for driving and riding purposes than those constructed with trap, the speaker desires to express his agreement therewith, having in mind some old roads which were resurfaced in 1895. These roads were built originally with trap-rock, and were thin macadam roads without telford foundation. Being badly worn, they were remacadamized with Tomkins Cove limestone. The old macadam was spiked up by the roller, and the limestone was spread and rolled down. These roads have given excellent service, and are in very good condition to-day, except where they have been partially destroyed by sewer construction and openings for various kinds of pipes. Mr. Graham.

The speaker's experience with limestone has been that without some binding material it is not possible to get it to bond within any reasonable length of time, without an excessive amount of rolling, so much rolling in fact as to sometimes crush the stone. In handling limestone for macadam, the speaker has made it a practice to use loam as a binder, being careful to use a clay loam, and not one which contains any considerable percentage of sand. Water is freely used, and the macadam is thoroughly rolled until the excess of binder runs on the surface ahead of the roller in the form of a thin grout, which by continued watering and rolling is finally forced from the surface of the macadam. A thin coat of screenings is then applied and rolled, after which a wearing coat of screenings is spread. This method gives very good results.

Though the speaker has made no experiments to ascertain whether it is true or not, he believes that the most efficient work is performed by steam road rollers when they are run at maximum rates of speed.

HOWARD J. COLE, Assoc. M. Am. Soc. C. E.—In Essex County, N. J., which contains the cities of Newark and Orange and the residential townships of East Orange, South Orange, Montclair, Bloomfield and Nutley, a park system has been inaugurated, and among the first constructions have been the roads. Mr. Cole.

The type of road adopted as most serviceable under existing con-

Mr. Cole. ditions is a telford-macadam, 8 ins. thick, consisting of a foundation 5 ins. deep, and 3 ins. of 1½-in. broken stone and screenings.

The subgrade was carefully rolled, after which the telford foundation was placed by hand and firmly chinked and then set in place by a 10-ton roller. After this, a coat of binder, barely ¼ in. thick, was placed on the telford, and then the 1½-in. stone was spread. The roller was again used until the small stone had been rolled to a good surface, when another thin coat of binder and screenings was spread, after which the road was watered and rolled until a satisfactory surface was secured.

The work so far has been constructed entirely from the trap rock of the Orange Mountains, and after nine months' use is in first-class condition. The cost of this work was 59 cents per square yard. About one mile of the roads of the park system has been built, but the plans call for the construction of about 40 miles of drives, of substantially the same character, in the parks and connecting parkways.

In the Mountain Reservation some earth roads are being built for temporary use, until the permanent administration roads are built. These roads, which are about 12 ft. wide, follow generally the lines of the old wood roads, with slight changes of alignment and grade, the cutting of any trees or shrubs being avoided as much as possible. The road is given a moderate crown, and good drainage gutters are made on each side, while at frequent intervals the water is carried off by cross-drains and culverts, the main object being to keep the road as dry as possible. During the past season these temporary roads have been used considerably by pedestrians, bicyclists and the driving public and, with but little attention to their maintenance, have stood the traffic well.

In the South Mountain Reservation, near Milburn, N. J., the Park Commission has assumed the care, custody and control of an old public road (Brookside Avenue) for a length of two miles. This road has been regraded and then dressed for a width of 12 ft. in the center with a coating of 1½-in. stone, which, after it had been compressed by a 2-ton horse roller, was about 2 ins. thick. After being thoroughly rolled, screenings were spread and the road again rolled. The cost of this improvement was $1 000 per mile for grading, and $1 000 per mile for broken stone. Thus, at a very reasonable expenditure, a dirt road was converted into a desirable road for pleasure driving.

Mr. Seaman. H. B. SEAMAN, M. Am. Soc. C. E.—Mr. Tomkins has proposed trap-rock roads with limestone binding, and Mr. Tillson has described a trap-rock road which was worn so rough that the wheels of a vehicle would jump from point to point of the larger stones. These two conditions illustrate cause and effect. The softer binding material wears down first, and leaves the harder stones projecting.

In replacing a number of macadam roads, the speaker found occasion

to use trap rock, with screenings of the same material. Water was used freely in rolling, and no trouble was experienced in getting the material to bind properly. The road was smooth as long as it lasted. Mr. Seaman.

GEORGE HILL, Assoc. M. Am. Soc. C. E.—When engaged on the geological survey of New Jersey, the speaker saw probably 20 miles of road apparently made of blue shale which had been broken into small sizes and dumped on the foundation prepared by breaking off the outcropping rock on the side of the road, the traffic working it down. Those roads were only slightly muddy, when the roads in the valleys and along stretches of ground untreated were practically impassable on account of the mud. They kept a good surface throughout the year, apparently without any special attention being given to drainage, which was probably secured through the undulating character of the road, and the numerous streams which crossed it. Mr. Hill.

On the seashore many miles of gravel surfacing are used, the practice being to shape up with sand, and surface with 4 ins. of clayey gravel; the gravel ranging in size from $\frac{1}{8}$ in. up to $1\frac{1}{2}$ ins., and the percentage of clay varying with the amount naturally present in the bank from which the clay is taken. Both surfaces are shaped with a road scraper of the simple construction usually found in country places, the more elaborate road machines being but seldom used. For compacting the surface, reliance is placed on the light traffic, and the passage of the carts which bring the material, and which are usually provided with 4-in. tires. To be kept in order the roads require constant attention, and resurfacing about every second year. No special provision is made for drainage, since the sand is pervious and consequently dry.

S. C. THOMPSON, M. Am. Soc. C. E.—Mr. Hill has covered a question which the speaker was about to ask, *i. e.*, what would be done in a country where there is no limestone or trap rock. The discussion has brought out pretty thoroughly what can be done in the way of a macadam road with limestone, or with trap. The speaker has lived in a section, however, where there is neither one nor the other, but where it was necessary to make as good roads as possible. The custom there was to make them of two kinds of gravel; one practically a dry gravel free from any admixture, and the other a hardpan. It was found that by mixing the two, making them thoroughly wet and using a 4-ton or 6-ton grooved roller, with a 4-in. face and a 4-in. groove, for combining them, and by going over the work repeatedly and finishing it with a smooth roller, that a surface could be obtained which would not only stand heavy traffic, but would also wear well and shed water. It made a very compact roof. In one case where the speaker had occasion to build an embankment for a special purpose, the gravel was mixed in that way; the roller and a water cart were kept going all the time, and the embankment was left over winter to provide for settlement. It was tested carefully, and in the spring Mr. Thompson.

Mr. Thompson. it was scarcely possible to discover that there had been any settlement; showing that such material could be used for roads and give excellent results. Of course, such roads do not wear as long as the macadam roads made from trap or limestone.

In the eastern part of Massachusetts there are a great many miles of those gravel roads, in many cases built with no hardpan at all, which stand the traffic admirably and do very good service, and the expense of building them is trifling. The ordinary way of building is simply to excavate, get a roadbed of sufficient width, fill in with gravel and roll it. In many cases the traffic itself takes the place of the roller. In that way a hard bed, and one that gives very good results, is obtained.

Mr. North. EDWARD P. NORTH, Vice-President, Am. Soc. C. E.—There seems to be some difference of opinion in regard to the relations between the foundation of a macadam road, and the treatment of the wearing surface. One engineer has said that he did not care for binding, and others have laid a great deal of stress upon it. The speaker would be justified, perhaps, in calling attention to the fact that the engineer who did not care for binding proposed a telford foundation, and the engineer who laid great stress on binding proposed a thin road on an earth surface. In building a thin road it is necessary to use the best possible binding, so as to produce a road that is both a wearing surface and a roof. With a telford foundation, however, this is not so absolutely necessary, as the stone, without being so well bound, will still make a tolerably good road.

A point which has been overlooked in this discussion is the influence of roughness in the surface of the stone used, on the ease with which it can be compacted, and on its general wearing qualities, not only in its freedom from "raveling," but in its ability to stand wear when kept so well watered as to resist breaking up from dry winds. Some stone with a decided "tooth" that is not otherwise desirable makes a very good macadam. In Saratoga Springs all the macadam streets are in very good condition, although the stone used is a calciferous sand rock (a sand stone bound by lime instead of silex), which is so weak that the edges of spawls can be broken off by a pressure of the thumb. On Broadway, a street that has a considerable amount of heavy traffic, as well as much fast driving, there was laid a 6-in. macadam on the old dirt roadbed, which lasted, with some maintenance, between 6 and 7 years before it required resurfacing.

The tooth of the stone undoubtedly had great influence in its resistance to wear, by checking or preventing the tendency of the stones to rub one another under passing loads, and the presence of a lime cement was also valuable, for it is doubtful if a pure sand stone of that strength would have worn as well. On the eastern face of the Palisades a stone decidedly harder than the average trap is found. It is called

"black jack," irrespective of its color. That stone, which is very smooth, is condemned by road-builders on account of the difficulty of compacting it and making it stay in a road, even after it is well puddled. Mr. North.

There will be substantial agreement in the statement that, if it is possible to make a thin road which will not break up, the stone will wear longer than if on a rigid foundation, because a stone cannot be easily broken by striking it when on soft earth. It breaks very easily, on the other hand, if struck when on a hard surface. So, between Telford and Macadam, Macadam was right in proposing to build a thin road. Material will wear longer without a telford foundation, if it is not forced into the subsoil by the traffic. This leads immediately to the consideration of the drainage of the road.

As long as the road stays dry and compact it is almost impossible to crush 2 ins. of well-compacted macadam into the soil. The speaker has seen a load weighing 2 or 3 tons on narrow-tired wheels drawn over such roads without injuring them. If it is possible to drain the roadbed, or to so shield it with the macadam that it will stay dry, it is a waste of material and a waste of money to build a thick road. If the roadbed cannot be kept dry enough to prevent the traffic from crushing through, of course more money must be put in the foundations. All engineers should remember, however, that monuments pay no interest, and however desirable they are as a matter of piety or beauty, monuments that cannot be seen are worthless, and that, as Mr. Lewis says, it is the length of the road that is valuable, and not the depth. Hence an engineer should make his brain save material by doing better work.

Mr. McClintock has said that in Massachusetts they put a certain thickness of porous gravel between their telford and the roadbed. The speaker is not satisfied with this practice. On a clay road, or on any road that is muddy in wet weather, the finer the material that is placed on it, the smaller will the apertures in the material be, and the more certainly will it prevent the mud from coming through. The speaker has used, both for highways and for railroads, a layer of very fine sand; in one instance sand so very fine that it was blowing sand. Five or six inches of it were put in clay cuts which were undrained at the time and stayed undrained for three years after, and broken stone or gravel was placed on the sand. The roadmaster said, at the end of three years' experience, that he had less trouble with the track on the sand in undrained cuts than he had with the track on embankments where there was no sand. A colander, if put in a bucket of water will sink, but if it is wrapped in cloth, or anything impervious to the water, it will float. So a macadam roadbed will float on an undrained clay surface, if material that will not permit the clay or mud to go through is placed between the two; whereas if coarse stones, macadam or tel-

Mr. North. ford, are put on soft material, as was the practice in Hartford, Conn., for instance, before Mr. Bunce took charge of the streets, the clay can be rolled up through the telford or macadam. The speaker believes this was done almost invariably in Hartford, and then the road was left as finished.

Mr. Pierce, of Bridgeport, built some 70 miles of 4-in. trap road, which was puddled or bound more with sand than with screenings. Of that 70 miles about half a mile broke up in the course of seven years. It broke through in two places, and there he added 3 ins. of stone. These roads lasted, with more than ordinarily heavy traffic for a town of that size, as he said, for seven years before it was necessary to resurface any of them, though, of course, they required some maintenance. His practice is interesting and instructive, as he did not underdrain his roads, nor did he use sand or other material impermeable to mud under the broken stone, but he puddled his roads carefully and kept his ditches open all the time. In the spring, when the grass started, he waited for a hot day and spread sand to a depth of about ½ in. through the gutters, left it there for a day or so, then scraped it up with a road machine and applied it in other places. The sand, under a hot sun, burnt and killed the young grass and weeds in a short time. That was understood to be all the drainage that the 70 miles of road had, except right in the town, where there were sewers.

There are other circumstances besides the first cost of a road which should govern an engineer in selecting the style of road or the material that he is to use. In the City of New York, for instance, a street cannot be paved, with the approval of the law, unless an assessment is made for it. When a street is once assessed, it cannot be assessed again. This is true in both the Boroughs of Manhattan and the Bronx. It is not so in Brooklyn. The practice, therefore, in New York since 1868 has been to build nothing except telford roads. Some of them have been 16 ins., and some 22 ins.; none less than 16 ins. deep. These roads have this advantage: when the traffic gets too heavy for a macadam road the telford foundation is very good, either for an ordinary granite or trap pavement; or, with a little dressing up and filling in at places, for an asphalt pavement. So, possibly, there is engineering justification, as well as legal justification, for building these heavy roads in New York. Building such a pavement in the country, however, results in the unproductive investment of capital.

In Vermont the assessed value of the State amounts to only $1 200 per mile of road. The equalized value of real and personal property subject to taxation, in the State of New York, for 1896, was $4 368 712 903. If the estimate of 123 000 miles of road in the State is correct, improving all the roads in the State at the cost of $10 000 per mile, as has been advocated, would confiscate over 27% of the above valuation. If the values assessed against the counties of New York, Kings

and Queens are taken from the total valuation, as above given, only about $4 000 per mile would be left, on an average, after a $10 000 improvement had been completed. And it is in the poorer portions of the country that the high cost of transportation falls with the most crushing force. Mr. North.

It is submitted that an engineer, or any one else, who proposes to improve the roads of the State of New York at the cost of $10 000 a mile, makes a mistake. It should be borne in mind that in the early practice of railroading, the cheapest possible roads were built. Those were better than any highway, and, as they reduced the cost of freightage, they not only earned money for the company owning the road, but also added to the wealth of the surrounding country; so that railroads which were originally built for as low a price as $10 000 per mile have so developed the wealth of the country through which they ran that the increased traffic has justified several rebuildings of the road, while the freight charges have been reduced to 8 or 10% of what they were when the road was opened. This would have been impossible unless the railroad had presented a cheaper means of transportation than the highway, and it would have been equally impossible to build railroads like the Pennsylvania Railroad, for instance, out of the resources of the country when entirely dependent on wagons for transportation.

Engineers having charge of either a district or a single line of road are urged to consider the possible advantage of diffused rather than of localized expenditure; that is, to make an effort to immediately bring the roads of the entire district up to the best standard of usefulness practicable, increasing the expenditure yearly until the roads reach the desired excellence. While there are areas of clay or sand that may require an immediate large expenditure for broken stone or gravel on their roads, most of the roads on the Atlantic Seaboard can be put in good order for, say, ten months of the year with a very small expenditure per mile, most of which will be concentrated on one or more bad places. Future expenditures should bring the roads up to continuous usefulness. This is not intended as a plea for poor roads, but to make any expenditure serviceable to the greatest area possible, and to admit of the marketing of produce through a longer period and at a lessened expense. It will be admitted that the poverty of the farming communities is due to the high cost of transporting their produce to the consumers, and any reduction of that cost must add an equal sum to their gains, and, consequently, to their ability to pay for improved highways.

T. McC. Leutzé, M. Am. Soc. C. E. (by letter).—The State of New York appropriated $50 000 to be spent in experimental "object lessons" for the farmers and dwellers in the country. Only the Schenectady and Troy road is actually under construction, but surveys Mr. Leutzé.

Mr. Leutzé

and plans are ready for other roads. One road in the first stage of construction is hardly an "object lesson." Nevertheless, the number of applications that have been filed for the improvement of roads is beyond expectation, and shows that the Supervisors of the various counties are fully alive to the necessity of good roads, and are anxious to take advantage of the offer of the State to pay half the cost.

Thinking it may be of interest, the writer gives herewith a list of the petitions received, from which it will be seen how totally inadequate is the sum of $50 000 to carry out the desires of the various counties.

Counties.	Petitions.	Miles.
Erie	6	48
Orange	8	141
Rockland	11	38
Monroe	15	102⅓
Columbia	1	2
Schenectady	1	2
Oneida	1	2½
Onondaga	3	2½
Rensselaer	4	17⅔
Totals	50	356

This would involve— at $10 000 a mile roughly—the large appropriation of $1 680 000 on the part of the State to cover the petitions already filed, and as the Legislature cannot appropriate more than $1 000 000 at a session, it is evident that some of the petitions will have to wait.

It would be pleasant to be able to build a road as it ought to be built; that is, a standard road with perfect tile side drainage, proper grades and slopes, cobble gutters, fences on embankments, and a substantial thickness of well-rolled macadam—the writer's idea of thickness being 8 ins. on a thoroughly rolled subgrade. Such are the roads that nearly all desire, but as soon as the price is mentioned, the elimination of items and quantities is demanded. Drainage is grudgingly admitted to be necessary, the fences are omitted, the macadam shrinks to a thin veneer, and the result is a cheap road. Take the Schenectady and Troy road, for instance. In the first plans the writer provided 4-in. tile side drains, cobble gutters and 8 ins. of macadam 18 ft. wide. The grades were better than in the present plan, but the tiles and cobble gutters had to be omitted, the grades changed, as excavation and embankment ran too high, and the macadam reduced to 6 ins. in thickness and 16 ft. in width. The writer does not lay so much stress on the width as on the thickness, in the sandy soil prevalent in that part of the State. It was even demanded that the use of the stone peculiar to that vicinity should be used in the macadam—

"Aqueduct Stone," a shale that would turn to clay in the first storm. This was happily averted, and the present State Engineer will insist on trap rock covering, at least, on all roads where macadam is to be used. Mr. Leutzé.

The writer consoles himself with the theory elucidated by Mr. North in an article in the *New York Mail and Express*, in which he suggests the propriety of making a road during the first year, that a farmer can use six months of the year where he could only use it three months before; to improve it in the following year, so that the farmer would be able to use it nine months instead of six months, etc., etc., and in this way, if first-class roads could not be built, "make the punishment fit the crime."

The Columbia County road is an entirely new one. It leaves the old road through the Shaker settlement at Mount Lebanon to the left, and, by following the contour of the hills, connects with the Massachusetts road (improved) at the State Line, and secures a 5% gradient over the entire mountain into Pittsfield. As some of the gradients on the old Shaker Road are 20%, 19%, 17%, etc., the advantage attained can be imagined. Economy here again demands a gravel covering, splendid material being handy for haul.

This road, including wire fencing, thorough drainage, one 40-ft. span bridge, one 48-in. wrought-iron pipe culvert, numerous cross-tile drains, and about 16 600 cu. yds. of material to be handled in grading the road, will cost about $9 000 for 6 500 ft.

There was considerable trouble in persuading the Shakers, who own all the lands in the vicinity, to grant the right of way, but after months of persuasion they granted it. It seems strange that a people which has preached isolation for nearly one hundred years should object the very first time that this realization of their doctrine was possible.

WARREN B. TRAVELL, Jun. Am. Soc. C. E. (by letter).—During the past year and a half the writer has done some experimental work with thin coverings for dirt roads, which may be of interest to engineers having to contend with similar conditions. The work was done in the Borough of Manhattan, on Fort Washington Avenue, which begins at One Hundred and Fifty-ninth Street and the Boulevard, and runs northerly to Inwood. Until the summer of 1897 this was a dirt road, but lightly traveled in the best of weather and quite impassable in times of rain. The soil is a micaceous sandy clay. Mr. Travell.

During that summer the writer spread, on a mile and a half of the road, a thin covering 15 ft. wide, using a variety of road material, with the express object of determining the smallest possible cost at which a dirt road having light traffic could be rendered respectable in New York City. There was no grading done, the only preparation being a simple scraping and rolling, which it was customary to give

Mr. Travell. the road about every week. Beginning at One Hundred and Fifty-ninth Street, the sections were spread with material as follows:

Section.	Location.	Length.	Material.
1.	159th–163d Sts..	1 523 ft.	2-in. Roa Hook gravel.
2.	163d –165th Sts..	420 ft.	¼-in. Roa Hook gravel screenings.
3.	165th–167th Sts..	554 ft.	¾-in. feldspar (no dust).
4.	167th–179th Sts..	3 157 ft.	2-in. Roa Hook gravel.
5.	179th–182d Sts..	813 ft.	feldspar screenings.
6.	182d –188th Sts..	1 652 ft.	¾-in. limestone (no dust).

The following are the itemized costs of the several sections:

SECTIONS Nos. 1 and 4.—2-in. Roa Hook Gravel.

Length	4 680 ft.
Width	15 ft.
Thickness	2 ins.
Cost:	
451 cu. yds. of material at $1.97 (delivered)	$888.47
Spreading, 213 hours at 25 cents	53.25
Sprinkling and rolling, 298 hours, at 50 cents	149.00
Superintendence, tools, etc	41.00
Total cost	$1 131.72
Cost per running foot	.2418
Cost per mile	1 277.02

SECTION No. 2.—Gravel Screenings.

Length	420 ft.
Width	15 ft.
Thickness	3 ins.
Cost:	
60 cu. yds. of material at $1.97	$118.20
Spreading, 24 hours	6.00
Sprinkling and rolling, 15 hours	7.50
Superintendence, tools, etc	3.00
Total cost	$134.70
Cost per running foot	.3207
Cost per mile	1 693.29

SECTION No. 3.—¾-in. Feldspar Stone.

Length	554 ft.
Width	15 ft.
Thickness	2 ins.
Cost:	
51 cu. yds. of material at $1.40	$71.40
Spreading, 22 hours	5.50
Hauling and spreading 12 cu. yds. of rotten stone earth	18.00
Sprinkling and rolling	17.00
Superintendence, tools, etc	8.00
Total cost	$119.90
Cost per running foot	.2178
Cost per mile	1 149.98

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SECTION No. 5.—Feldspar Screenings.

Length	813 ft.
Width	15 ft.
Thickness	2 ins.
Cost:	
70 cu. yds. of material at $1.40	$98.00
Spreading, 25 hours	6.25
Sprinkling and rolling, 32 hours	16.00
Superintendence, tools, etc.	4.00
Total cost	$124.25
Cost per running foot	.1528
Cost per mile	806.78

SECTION No. 6.—¾-in. Limestone.

Length	1 652 ft.
Width	15 ft.
Thickness	2 ins.
Cost:	
146 cu. yds. of material at $1.40	$204.40
Spreading, 48 hours	12.00
Hauling and spreading 27 cu. yds. of rotten stone, earth	40.50
Sprinkling and rolling	40.00
Superintendence, tools, etc.	18.00
Total cost	$314.90
Cost per running foot	.1906
Cost per mile	1 006.37

More than a year has now passed since this work was completed, no new material having been added in the meantime, except a few loads of gravel screenings. The section between One Hundred and Fifty-ninth and One Hundred and Sixty-fifth Streets has had to stand an unusually heavy traffic, owing to the use of this stretch by trucks hauling material for the macadamizing of Boulevard Lafayette. The road shows a decided improvement, however, over its former condition, though it is somewhat cut up by ruts, and the dirt has broken through in a few places. The short strips covered with gravel screenings and feldspar screenings were not satisfactory. The feldspar screenings were quickly ground into dust or mud, while the gravel screenings resembled sand, and would not compact under traffic. The rest of the road has preserved its surface very well. The best sections are those covered with ¾-in. limestone and ¾-in. feldspar, materials which behaved especially well on hills. The coarse gravel furnishes a hard, firm surface, though not as smooth as that of the broken stone. It will be noticed that these three best sections cost between $1 000 and $1 280 per mile, or from 19 to 24 cents per running foot. In localities where stone and labor are cheaper, the cost would be considerably less. The writer wishes to bring out the point that on

Mr. Travell. this avenue, where the construction of an expensive pavement was entirely out of the question, and where the traffic consists chiefly of carriages and light delivery wagons, a roadway has been built which, as regards its present utility, is equal to a pavement costing ten times as much.

The limestone used was from the Tomkins Cove quarry. Its analysis may be found in the *Transactions*, Am. Soc. C. E., Vol. VIII, page 98. The stone referred to as feldspar came from Clinton Point, south of Poughkeepsie, N. Y. Its analysis is:

Silica	63.24	per cent.
Alumina and sesquioxide of iron	19.52	"
Lime	3.80	"
Magnesia	1.29	"
Carbonic acid	2.72	"
Alkalis, etc	9.43	"
	100.00	"

The average crushing strength of cubes of less than 2 ins. is 30 580 lbs. per square inch.

In the City of New York it is illegal to assess a piece of property for more than half its valuation at one time, so it is customary to allow a street or road to remain unpaved until the property increases in value sufficiently to stand the assessment for an expensive, permanent pavement. After this first pavement is laid, the city pays for all maintenance and repaving, but until this time the newly opened street or suburban road must struggle through a long period of growth with its surface quite impassable for at least three months of the year, and in poor condition during the remaining nine. This period of growth is, of all times, the most critical in the history of a locality —a time when, if at all, the city or county should extend its aid, and, by comparatively small expenditures, maintain such streets in a respectable condition until the permanent pavement is laid.

Such assistance would increase valuations so greatly that the increased taxation would pay for the improvement many times over, and, by thus fostering the growth of the locality, would hasten the time when the expense of a better improvement could well be afforded.

Mr. Cudworth. F. G. CUDWORTH, Esq. (by letter).—The writer, under the immediate direction of Edward P. North, M. Am. Soc. C. E., then Consulting Engineer of the Department of Public Works, New York City, had charge of the resurfacing of Seventh Avenue, between One Hundred and Tenth and One Hundred and Forty-fifth Streets, in the summer and fall of 1897. The area resurfaced was 81 675 sq. yds., and the average depth of material was, approximately, 3 ins.

The old roadbed was not broken up to a depth of 3 or 4 ins. by pick points in the wheels of the roller, but the surface, after a thorough

cleaning by scraping with stub wire brooms, was scored or pitted by hand labor with pickaxes, the pits being from 8 to 14 ins. apart. The old surface was in a satisfactorily compact condition, and the intention was to retain it as nearly intact as possible, and yet produce such roughness as would effectually prevent the sliding of the new material. On the roadbed thus prepared the new material was spread to the required depth, and the roller was passed over it twice without the addition of screenings or water. Then the entire surface was covered with trap-rock screenings containing about 20% of flour, and water was applied until the whole was thoroughly wet. The rolling was kept up constantly during the wetting, and, with the addition of more screenings, was continued until the new material was thoroughly consolidated, and enough screenings had been forced in to fill all voids in the coarse stone, and bring a thin mortar to the surface in front of the roller. Each block (80 ft. x 220 ft.) after being puddled in this manner was allowed to dry out for 10 or 12 hours, and was then covered with coarse screenings to the depth of $\frac{1}{4}$ in., and opened to traffic. Mr Cudworth.

To estimate the time and cost per square yard, accounts were carefully kept on eleven out of the thirty-five blocks, aggregating an area of 21 908.3 sq. yds. The time of roller work on this area was 464$\frac{1}{2}$ hours, giving as an average 47.15 sq. yds. finished per hour, with extremes of 38.4 and 65.1 sq. yds. per hour, or, in other words, the average time per 1 000 sq. yds. was 21.2 hours.

The cost of rolling per hour, allowing one-tenth of the watchman's time, was as follows:

Engineer	.30
Fireman	.15
Coal and oil	.40
Sprinkling	.30
Watchman	.15
Total	$1.30, or 2.765 cents per square yard.

The following amounts should be added to obtain the labor cost of resurfacing:

Rolling per square yard	$0.02765
Scraping and sweeping	0.02000
Picking old surface	0.01500
Spreading stone	0.02000
	$0.08265

or about 8$\frac{1}{4}$ cents per square yard.

The amount of material paid for by the contractors and placed on the avenue was: 8 878 cu. yds. of 2-in. trap rock, and 4 763 cu. yds. of trap screenings. It will be noticed that the quantity of trap delivered overruns the assumed quantity on the road by about 30%, or, in other

Mr. Cudworth.

words, 3.9 ins. of broken stone were spread on the road, and 2.1 ins. of screenings were added. There was no opportunity for settlement in this instance. The average thickness, however, may have been underestimated, though the contractor did not expect to put on over $2\frac{3}{4}$ ins. of compacted material, plus $\frac{1}{4}$ in. of screenings as a top dressing.

The work was finished in the latter part of December, 1897. No difficulty was experienced from the stone creeping in front of the roller, and no part of the road has at any time broken up. Seventh Avenue, in consequence of the repaving of Eighth Avenue and the delapidated pavement on Lenox (or Sixth) avenue, has had an unusual amount of heavy traffic since the completion of this work, and there is also probably more fast driving there than on any other street or road in the world.

Mr. McCann.

T. H. McCann, M. Am. Soc. C. E. (by letter).—During the summer of 1890 the writer was called upon to take charge of the repairing of about 5 miles of telford and 2 miles of macadam roads in North Hudson County, N. J. These roads ran through five different towns, which supplied the necessary crushed stone, but the money to pay for the labor was subscribed by public-spirited citizens, one of whom, Col. E. A. Stevens, purchased for the work a 15-ton steam roller at a cost of $5 000.

The widths of the telford roads ranged from 20 to 30 ft., and the width of the macadam roads was 12 ft. The former had been constructed in a first-class manner thirteen years previous, but remained neglected up to the time of the repairing, and were worn down to the foundations; the latter were old, unscientifically constructed, stone roads in very bad condition.

The method of repairing was as follows: After the gutters, culverts and drains had been thoroughly cleaned out and graded, and the road surface cleaned of mud and slush, two courses of crushed trap stone, sufficient to bring the surface to grade, were applied to the foundation. The first course consisted of $2\frac{1}{2}$-in. stone, over which was sprinkled selected dry loam; upon this was spread $1\frac{1}{2}$-in. stone, and, after a lavish use of water supplied by the Water Company without charge, the whole was rolled until the binding came to the surface in puddle. This was swept off, trap screenings were spread on while the surface was still wet, and the road again thoroughly rolled, when it was ready for use. These repairs were done longitudinally, taking half the width of the road at a time. The plant consisted of a cart, a watering wagon and the steam roller. The working gang was composed of five men and a foreman. This force was engaged during four months at an expense of about 8 cents per square yard of road. This, with the cost of the stone furnished by the towns, made a total cost of about 20 cents per square yard.

From the foregoing and similar experiences, the writer is convinced

that this method of repairing is preferable to that of continuous patching in spots. In other words, it would seem to be better to allow a road to wear down a few inches, and then repair it as a whole. Mr. McCann.

As to the use of binder on new roads, the writer agrees with Mr. Owen that this is a matter of judgment, depending upon the locality, the kind of stone used, the nature of the traffic and the speed with which it is necessary to complete the work. The writer's experience with trap telford has been similar to Mr. Harrison's, *i. e.*, that excellent roads can be constructed without earth binder, but more time will be required.

One serious concern to the engineer is the construction of roads over swamps and peat bogs. After considerable experience in this line the writer has come to the following conclusions: If the line is over a soft, deep, wet and yielding swamp it may be the cheapest and best plan, provided timber is handy, to float the road on a raft made of long poles; a bottom course laid longitudinally, with broken joints, a second course laid transversely and covered with brush. The grade line should be the lowest permissible, and the filling free from deleterious matter, and the lightest obtainable, in order to reduce the weight as much as possible. Side-ditching should not be done along these roads, as this destroys the sustaining power of the peat; but drains should be made a considerable distance from the road. This also applies where embankments are constructed over swamps.

In filling in over peat bogs, it seldom happens that the embankment sinks to the hard underlying bottom, and in making preliminary estimates of the amount of filling necessary, it is very difficult to determine the correct settlement. It can only be said that on ordinary marshes it is not safe to assume a settlement of less than $1\frac{1}{2}$ ft. for each foot of height above the surface of the swamp for embankments whose grade lines are from 2 to 5 ft. above the peat surface.

As the writer stated in his discussion on "The Compressibility of Salt Marsh Under the Weight of Earth-Fill,"* there is no constant relation between the depth of the marsh to hard bottom, and the height of the fill above its surface. This relation is largely dependent on the nature of the swamp material. Observing the sinking of a sounding rod, and taking borings to hard bottom, will often aid in forming judgment in this matter. As stated before, it is desirable in constructing roads of this kind, to keep the grade line as low as possible. If the road is not to be used for railroad purposes, it need not be brought to extreme high-water line over a swamp where there are no currents. The inconvenience to the public from a foot or so of water on the road during the short period of an occasional extreme high water may not be of such a serious nature as to warrant the ex-

* *Transactions*, Am. Soc. C. E., Vol. xxxvii, p. 219.

Mr. McCann. pense of filling above that line. The first macadam covering should be of the thinnest, as there is sure to be some settlement which can be made good by the addition of stone from time to time, finally making a considerable thickness of metal on the road. Telford is not to be recommended on swamp roads.

A few years ago the writer constructed a trolley road over some tidal swamp land. It was a double-track line, each track being laid on the outer side of an old plank road. This old road had been made, many years before, by laying 3-in. planks transversely on the surface of the meadow. The grade line was about 2 ft. above the meadow, and about 2 ft. below occasional extreme high tide. The depth of the filling over the planks varied from 4 to 6 ft., and the depth to hard bottom was from 30 to 60 ft. In constructing the trolley line it was necessary to widen the road on either side about 3 ft. beyond the ends of the old planks, and to excavate 1 ft. for the subgrade. In doing this, great care was taken not to disturb or cut the peat surface, which was more or less firm, although in places not firm enough for a person to walk upon without sinking nearly to the knees. The filling was boiler-house cinders.

The trolley road was in operation over a year before any resurfacing was necessary, and then the settlement was found to be fairly uniform along the track. About once a year this road is submerged 18 ins. by the extreme high tide, thus making it necessary, for a few hours, to draw the cars by horses, the company having no authority to raise the grade.

In another embankment, built in 1897, over a tidal swamp on the shores of the Passaic River, a settlement of only 2 ins. was found after the road had been subjected to considerable heavy traffic for one year. This road is 80 ft. wide, with a 40-ft. carriageway. The grade line is an incline, varying from 4 to 20 ft. above the surface of the marsh. The swamp was a firm peat bog at the elevation of mean high water, but too soft for a person to walk upon without sinking nearly to the knees. The depth to hard bottom was 8 ft. below the bog surface. Borings into the embankment disclosed the fact that the compression of the marsh was nearly uniform; that is to say, the bottom of the 24-ft. fill was only 1 ft. lower than that of the 8-ft. fill. The preliminary estimate was 2 000 cu. yds. in excess of the quantity determined by the cross-section borings.

Mr. Burke. M. D. BURKE, M. Am. Soc. C. E. (by letter).—The writer does not expect to adduce anything new upon this subject, but wishes to offer a suggestion or two regarding the definitions of terms used by others in the discussion.

All agree that "thorough drainage" is necessary, yet no one has very clearly defined the term, or described the means by which it is to be secured. If the impression be conveyed that thorough drainage

is supplied when ditches or conduits are provided by which the rainfall is conducted from the roadway, the idea will only be correct in exceptional cases. In general, the soil supporting or underlying the roadway must be drained to give it the sustaining power to carry the traffic. If the soil underlying a level road becomes saturated, or if the soil water rises to the level of the roadway, no macadam or telford covering that can be placed upon it will sustain any considerable traffic. The drainage, therefore, to be thorough and efficient, must lower the water level 2 ft. or more below the roadbed. Mr. Burke.

Upon all gradients where the subsoil is not composed of sand or gravel, from which the ground water finds a convenient exit, the plane of the road will cut across lines or planes of pervious material, through or along which the water will reach the surface of the ground beneath the stone covering of the roadway, and destroy, not only the bearing power of the soil, but also the cohesion of the metal. If these currents be not intercepted (and they are seldom visible during the construction of the road), and the moisture conducted from them to the side drains, the drainage will not be thorough. Tile drains beneath the roadway are likely to become broken or clogged. The writer has found that trenches filled with porous material, such as coarse sand, sandy gravel or broken stone and sand, leading diagonally to the side drains are more reliable, and cost less, than any other form of subsoil drain that has come to his notice. The side drains described by Mr. McClintock will generally be efficient, but there are many localities where the diagonal subsoil drain, or a substitute for it, is necessary.

All clay soils that are to support macadam or telford roadways, after being properly drained and compacted by rolling, should be covered with a layer of coarse sand or fine gravel, and at frequent intervals this layer should extend to, and be efficiently connected with, the side drains. It is well to understand that the purpose of this material is to form a pervious stratum beneath the macadam, which will intercept the moisture escaping from the soil, and lead it to the side drains, rather than into the covering of stone, where it is likely to freeze and destroy the solidity of the road covering.

Upon any roadway covered with metal to a depth of 6 ins. or more, it is obvious that the sole use of the lower portion of the metal is to distribute the weight upon the soil beneath it. It follows, therefore, that the bottom or first course of stone can consist of any convenient material that is suited to that purpose. If the material be limestone, it must be free from shale, for upon exposure to the weather that soon becomes clay, which the frost uses as a disintegrating element in the roadway. If it be sandstone, it must have sufficient strength to resist crushing, and to prevent displacement by the harder fragments of stone overlying it when they are acted upon by the concussions and pressure of the traffic. Whatever the material may be, it is evident

Mr. Burke. that, where it is economical to do so, a compact limestone, a dense, hard sandstone, an inferior granite, or gneiss, will serve for this part of the road covering almost as well as the hardest trap rock. Whether it be placed in the form of a telford pavement, or broken into cubical fragments, the sides of which measure not more than 2 or 3 ins., will matter little, as the advantage will generally lie with that which becomes most compact under the roller, and can be placed in that form at the least cost. Under the pressure of the roller, the sand will be forced into the spaces between the stones, while if the sand be omitted, those spaces will be filled with clay, a condition adverse to drainage and conducive to destruction by the action of frost.

The wearing surface should be composed of the most refractory material, obtainable at reasonable cost, that can be united into a compact mass. The whin-stones, or trap rocks, and the harder granites, are the most desirable, but the limestones are most widely distributed and generally available. No valid reason can be assigned for making this coat more than 3 or 4 ins. in thickness. The fragments composing it should not be too small, as then they are more easily displaced, and consequently wear more rapidly. All crevices between them should be filled with finely crushed rock, be thoroughly worked in with steel brooms, while dry, and then be wetted and rolled until the surface is perfectly smooth and hard. No clay or other substance readily soluble in water should be used as a binder or for any other purpose. It is very pleasant to see the beautiful surface that can be produced so readily, during the summer and autumn months, by rolling the clay or loam with the crushed stone, but when the frost enters and not only picks the lock, but destroys the entire combination, the results are very discouraging. A sharp silicious sand is sometimes necessary to secure the requisite bond, and in the early repairs of the road it is probably the best material, if sparingly applied; but when dry it affords considerable dust. When the road is constructed of limestone, the screenings should be used without separating the dust from them, provided the stone was clean when it went to the crusher. Limestone screenings may be used with whinstone or granite, with which they will readily form a bond, and inasmuch as the crushing of the harder stones seldom affords sufficient fine material for completing the roadway, their use as a binder is quite common, and is generally satisfactory. In form, the fragments constituting the wearing surface should be as nearly cubical as can be obtained from crushers, and in size, they should not exceed 2 ins. or be less than $1\frac{1}{2}$ ins.

On a new road, the most troublesome factor is the steel-clad hoof of the roadster when traveling at high speed, as the blow which it strikes is likely to loosen fragments of rock, and a species of raveling out follows, if the defect be not remedied. No better remedy is

known to the writer than to keep the surface lightly covered with screenings, and have a trusty man with proper tools make frequent repairs of the incipient damages until they cease to appear. Mr. Burke.

The form to be given to the roadway should be such as to cause the travel to be distributed over its entire surface. The high crown will cause the traffic to follow the center of the roadway. No sensible horse will travel upon a side hill when he can as easily go on the top of it. The low flat curve will retain no water upon its surface, and will generally distribute the traffic effectually. There is no sensible method of maintaining roadways other than that of constant inspection and repairs. No road can be said to be in proper repair when it is thickly covered with dust or mud, so that cleaning and repairing should not be separated.

When the telford or bottom course of broken stone is omitted, and the soil is smoothed, drained and compacted, and has a thin layer of broken stone or gravel rolled directly into it, it becomes the thin road so interestingly described by Mr. Travell. Plainly, this form of road is adapted to the lanes and byways of the country, and the cost places it within the reach of the farmer, but its construction, and particularly its maintenance, requires appliances and skill which are not commonly used in the work done on country roads. Millions of dollars are annually expended in the United States in building and maintaining macadam and gravel streets and roads, but the methods used are in no way similar to those described in this discussion, and the results are not so beneficial as they might be, were the work done under skilled supervision.

HERMAN CONROW, Jun. Am. Soc. C. E. (by letter).—The question of the elasticity of a road seldom receives the consideration it deserves. During the summer of 1897 the writer had occasion to design and build a driveway for a large estate in Dutchess County, N. Y., where it was especially required that the road when finished should not be too hard. In order to accomplish this, screened gravel, varying in size from ¼ in. to ¾ in., was used for the top coat. This was evenly spread to a depth of 3 ins., on a 6-in. broken stone foundation, and then roughly wet and rolled. No binder was used, as enough soil adhered to the gravel to make it pack readily. The gravel was easily rolled solid, and, after drying, the surface was smooth and firm, making an ideal road for driving. Later experience proved that this road was capable of bearing considerable hauling without showing unusual signs of wear. Roads in the same neighborhood, made of a reddish iron ore, are most excellent for driving when in a dry condition, but become soft and sticky after a long-continued rain. For park purposes, with only light driving, such a road would give satisfaction because of its great elasticity. Mr. Conrow.

Along the banks of the upper Hudson are enormous deposits of

Mr. Conrow. gravel, occurring in pits of great depth, frequently 40 ft. or more. These deposits are composed almost entirely of smooth stones, with enough clayey material to hold them firmly together. When excavated, the stones adhere to each other in great lumps, and very much resemble concrete. The stones are of all sizes, from that of a pea to boulders as large as a man's head. The stone is soft and unfit for roads where heavy hauling occurs, but for driving roads it is an excellent material, making a firm road, yet very elastic.

In Burlington County, N. J., considerable difficulty has been experienced from building the roads too hard. In some instances a coating of gravel about 1 in. thick, spread over the macadam, has given the desired effect of reducing the extreme hardness. Upon one of the main roads leading into Camden, N. J., over which many hundreds of loads of vegetables are carted daily to Philadelphia, it is the custom for the drivers, as the trip is usually made at night, to sleep on the homeward journey, allowing the team to drive itself. It is a matter of interest that teams under such conditions are frequently seen traveling at the side of the road on dirt and sand—where the draught is much more difficult—in preference to drawing the wagon over the smooth but painfully hard telford. No doubt if horses had a voice in the matter, the question of the elasticity of roads would receive a great deal more attention than it does now.

Mr. LeConte. L. J. LeConte, M. Am. Soc. C. E. (by letter).—An engineer's opinions are based largely upon his personal experience and observation in his immediate neighborhood. The writer has given much attention to long-time tests of both telford and macadam roads made of stone from the same quarries.

His observations lead him to the conviction that a thin macadam pavement, 5 to 6 ins. thick or less, cannot be maintained under moderately heavy traffic, except when underlaid by unusually good natural soil. Hence, its economic application is quite limited, particularly where good stone is scarce. Time has shown conclusively that many of Macadam's "principles" are errors of judgment, *e. g.*, disregarding the nature of the soil, and laying the crushed rock directly upon the soft ground. Imperviousness to water was also particularly harped upon, a perfection difficult to obtain, in any case, and impossible to maintain. When the subsoil is not readily softened by water, or when the pavement is properly drained, permeability is not an objectionable feature.

The telford pavements of to-day meet the ordinary requirements of good roads better and are cheaper than macadam, and at the same time are more practical in every way in their adaptability to changing conditions. They are especially desirable on soft and wet ground.

In most States the highways pass through regions which can only supply second-class stone. In such cases the telford type is by far the

more economical, the expensive portion of the pavement being confined to the top 3 ins. of road metal proper—the main bulk below being composed of second or third class stone. Mr. LeConte.

One of the best object lessons, showing the intrinsic value of the telford pavement has been noted in connection with the study of the old telford roads at and near Oakland, Cal. Many of these are now twenty years old, and, as to repairs, have been shamefully neglected. Subjected to moderately heavy traffic, these roads have worn down well into the foundation course, presenting a surface nearly as rough as an old cobblestone pavement. These roads are now being repaired with remarkable success at a very small cost, a roadway for all practical purposes as good as new being obtained at the trifling expense of 18 to 27 cents per square yard. The roads are repaired as follows: *First*, the old subpavement is soaked with water so as to soften the foundation somewhat; *second*, a 15 to 20-ton steam roller is used to crush and mash down the rough surface, giving a proper crown and shape to the finished surface, and new material is added, if necessary; *third*, there is put on a uniform layer of from 2 to 3 ins. of first-class road metal composed of either trap or basalt. This layer is sprinkled and well rolled with the 15-ton roller, using as a binder some neighboring road detritus mixed with sharp sand.

Mr. McClintock's remarks relating to the economic importance of making use of the entire output from the crushers cannot be too strongly commended; but this economic principle should be extended to include the gross output of the quarries as well. Exclusive specifications cannot preclude the public from paying for the gross output of the quarries, whether it is made use of or not.

It is pleasing to note the substantial efforts being made in Massachusetts toward educating the public to fully appreciate the true value and importance of good roads. Taking a broad view of the question, it may be safely stated that bad roads cause farmers more financial loss annually than all the fluctuations in market values combined. It costs the farmers from 25 to 30 cents a ton per mile to get their crops to market, while the cost of hauling on good roads is only from 6 to 10 cents per mile. This unnecessary tax paid annually by the farmers because of bad roads is correctly estimated to be high up in the millions for each State in the Union.

W. C. Foster, Esq. (by letter).—In 1897, the Borough of Lodi, a small municipality in Bergen County, N. J., voted to macadamize and otherwise improve certain of its roads and streets. The appropriation for this work was very small in proportion to the territory it was wished to cover, being but $12 000. For this amount it was desired to grade and macadamize about 4½ miles of streets. It was, of course, impossible to do so with such a small sum, but there was sufficient to grade the 4½ miles and to macadamize about 3 miles. Mr. Foster.

Mr. Foster. The total excavation in the grading of the different streets was 11 668 cu. yds., which was used in filling up low places in the roads, and in widening the banks. The grades were kept as low as possible, the minimum being 0.8%, except in one or two instances, where too great damage to adjoining property would be done, or where the adoption of this grade would cause heavier work than the appropriation warranted. There were only one or two places where a lighter grade was used, and in these places there was not much water to be taken care of. These lengths were short—not over a few hundred feet long, and were located mainly at summits. Many of the streets were so narrow that nearly all the travel would be confined to the center, and, therefore, a heavy crown was adopted.

The material encountered in the subgrade varied greatly, and some of it made an exceedingly poor foundation for a macadam road. Loose, dead, shifting sand, sharp building sand, loam, hard, red clay, and a soft, wet, springy foundation were found, and these sometimes changed from one to the other in a very short distance. The funds being so limited, the foundation work was confined to excavating the worst places, and filling them in with the most suitable material at hand. Where shifting sand was encountered it was found that it could be consolidated sometimes by slightly dampening it with the watering cart, and sometimes by scattering a small quantity of broken stone over it. Some of the spongy material was not cut through by the roller, yet, after the roller had passed, it immediately rose from 1 to 2 ins. or nearly to its original level. After the subgrade had been formed, it was thoroughly rolled, until in fact the wagons used for hauling the stone could be driven over it without forming ruts.

Trap rock was then spread over the subgrade to a depth of 5.67 ins. for 4-in. macadam and 7.38 ins. for 6-in. macadam. The thickness of the stone was from 5½ to 6 ins. on 4-in. work, and from 7¼ to 7½ ins. on 6-in. work. These thicknesses were calculated from the actual car measurements, and from the number of square yards laid. In order that these thicknesses might not be exceeded, levels at 50-ft. intervals were frequently taken on the subgrade, the loose stone, and the stone after rolling.

The trap rock was rolled dry until the required final thickness was reached. By making an experiment upon a piece of old macadamized road, the requisite thickness of loose stone was determined. The rolling of the stone was continued until a horse and wagon could be driven over it at a walk without pieces being kicked out, and until, in walking over it, the stones did not move under the foot.

The stone was broken and screened to such a size that it would pass over a hole 1⅛ ins. in diameter, and through one 2½ ins. in diameter. The writer thinks that larger sizes would have given better results, and in any future work he would use larger stone on the sur-

face, and if for economy it became necessary to use two sizes, would place the smaller on the bottom. Mr. Foster.

Upon the completion of the trap-rock work, fine limestone from Tomkins Cove, containing a large proportion of dust, was spread broadcast over the surface with shovels, watered and rolled until the interstices were completely filled and a very thin coating remained on the surface. As fast as the limestone disappeared, during the rolling, more was spread. During the process of rolling it was found necessary, as a rule, to keep the watering cart immediately in front of the roller, as otherwise the limestone would become sticky and pick up the road in patches. Rolling and watering were continued until the water flushed ahead of the roller, and the surface was covered with a liquid paste. If, during this process, the subgrade became so soft as to allow the wheel tracks of the roller to show in the stone work, work was stopped on that section, and the road-bed allowed to dry out for a day or so, and then the work was completed. In fact, it was found to greatly benefit the road to practically complete it, allow it to dry for a few days, and then go over it a few times with the watering cart and roller.

From observations made during the construction of these roads, it is the opinion of the writer that it would be of great benefit to them to sprinkle the surface immediately with a layer of sharp building sand from $\frac{1}{8}$ in. to $\frac{1}{4}$ in. thick, and to thoroughly water and roll it, in order to hasten the chemical action believed to take place.

Until the first winter has passed, it is important to prevent the limestone dust from being blown off the surface, and this can be easily accomplished by the occasional use of the sprinkling cart. After the first winter this precaution is unnecessary, and the surface may be swept, if desired, when the road will present a perfectly clean and smooth surface. Roads built in this manner do not soften in wet weather, or when the frost is coming out of the ground in the spring, nearly as much as those in which clay is used as a binder.

A piece of 4-in. road about 3 500 ft. long, built in the fall of 1897, did not ravel at all during the past summer, although it was not sprinkled. It presented a clean, smooth surface of trap. The travel over this section of road averages 130 wagons per day, from 7 A. M. to 6 P. M., some of them being very heavily loaded, and all having narrow tires.

A section of about 3 000 ft. of road, built in a defective manner by the contractor, was swept a few weeks after the contractor had abandoned it, as clean as it could be with steel street brooms, and opened to travel. Though a great deal of stone was hauled over it in very dry weather it did not ravel where it had been built with any reasonable respect for the specifications. The drippings from the watering cart in passing back and forth kept it in excellent condition.

Mr. Foster. Rain seems to have a different effect on the road than the water from the cart, and where the final rolling can be done during a rain-storm, the road becomes cemented up much more quickly.

The rolling was all done by a 12½-ton steam roller. The limestone dust is not washed off the road, but seems to form a sticky paste and remain on the surface until it is gradually blown off by the wind.

A short time after these roads were completed, considerable heavy hauling was done over a portion of them. For about five weeks at least two to four loads, of 5 to 7½ tons each, were hauled over them daily, in wagons, having tires about 2 ins. broad. Not even a wheel-mark is to be seen on either the 4-in. or 6-in. work. The regular traffic over the 6-in. road averages 308 wagons per day, from 7 A. M. to 6 P. M., the loads running from a light wagon to about 4 tons.

The larger part of the work was completed during the summer of 1898. One short section, finished in 1897, seems to be better to-day than when it was first built.

The total sum available for all purposes—advertising, printing, bonds, engineering, first six-months' interest, and construction, was a little more than $12 700. The following table shows the amount and details of the work done. In addition to the items given in the table the new work was kept sprinkled for about two months after completion, and a balance of nearly $50 was left.

Excavation	11 668 cu. yds.
Ballast foundation	342 sq. yds.
4-in. macadam	18 430.8 sq. yds.
6-in. macadam	4 771.1 sq. yds.
Cast-iron pipe culverts	233.8 lin. ft.
Cobble paving	131.2 sq. yds.
Length of street graded	4.6 miles.
Length of street macadamized	3 miles.
Average thickness of loose trap rock on 4-in. work	5.67 ins.
Average thickness of loose trap rock on 6-in. work	7.38 "
Quantity of 4-in. macadam 1 cu. yd. of trap rock will lay	6.348 sq. yds.
Quantity of 6-in. macadam 1 cu. yd. of trap rock will lay	4.878 sq. yds.
Quantity of either 4-in. or 6-in. macadam 1 cu. yd. of limestone will complete	21 sq. yds.
Cost of rolling, per square yard of completed macadam	$0.0412
Average number of square yards of completed work done by roller per day	314 sq. yds.

JAMES OWEN, M. Am. Soc. C. E.—Mr. North has stated that he considered the practice in building deep roads, such as telford roads, was not to use packing, but that thin roads required packing. Unfortunately, the speaker builds the deep roads only, and always uses packing, so he is rather departing from the general practice. Mr. Owen.

The speaker wishes to suggest one thought connected with this view, *i. e.*, that the *desideratum* for the surface of a road, either of telford or macadam, is a homogeneous mass. There should be a mass consisting of stones so thoroughly wedged together that there could be no extraneous material between the particles; and they should have a mechanical bond. The speaker has seen a piece of macadam 10 x 8 ft. square taken up bodily, and it seemed to be as strong and as stiff as a piece of flagging. That is what should be accomplished, if possible. It is the practice of the speaker to use no more packing than is necessary to get this bond; that as the pressure by rolling or by wheel travel comes on the broken stone during wet weather, a large proportion of packing is squeezed to the top in that way. On that theory, of course, the more packing there is, the muddier will be the road. If in a trap-rock road the trap-rock screenings are used, unless there is sufficient cementing power in the trap rock (the Palisades trap contains a great deal more lime than the Orange Mountain trap), mechanical binding will not be secured. The interstices only will be filled up with this dust which cannot get out, and the ideal condition is not attained. This brings up the question of rolling. The speaker believes that the shape of the stones governs the amount of rolling required. Stones which break cubically take less rolling to get them down than stones which fracture with flat surfaces. As to the necessity of breaking up the surface of an old roadway to repair it, the speaker is glad to learn that Mr. Cudworth did not use the ruthless forks in a roller, but merely picked the road. An old road is resurfaced because it is too rough for travel, and the speaker's experience has been that a road in that condition needs no picking or breaking, and that very satisfactory results will be obtained by putting the stone on top of the old surface. He has repaired a great many miles of road in that way, with very satisfactory results.